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Survey of urban nutrient inputs on the Swan Coastal Plain

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Survey of urban nutrient inputs on the Swan Coastal Plain

Coastal Catchment Initiative project

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Department of Water

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Summary

The rivers and estuaries of Western Australia's Swan Coastal Plain are being adversely impacted by the land uses in their catchments. Excess nutrients reaching the waterways can promote overabundant plant growth in these naturally oligotrophic systems. Nutrient sources include agricultural properties, fertilisers from urban areas, animal and human waste, and industrial discharge.

This survey's aim was to quantify the nutrient inputs (nitrogen and phosphorus) to the Swan Coastal Plain's residential urban land. It complements similar surveys of agricultural land uses undertaken by the Department of Agriculture and Food WA.

This survey was designed to determine nutrient input rates (kg/ha/year) – including fertiliser and waste from cats and dogs – for urban residential lots with varying characteristics, namely:

- lot size
- age of dwelling
- type of dwelling
- location
- whether occupied by the property owner or lessee.

Approximately 7000 surveys were delivered to 17 locations (20 suburbs) in Western Australia's Swan-Canning, Geographe Bay and Peel-Harvey catchments. Of these, 1206 surveys were returned (17.2% response rate). The median input rates (to lots) from fertilisers and pets were 84.1 kg/ha/year for nitrogen and 19.7 kg/ha/year for phosphorus. Nitrogen input was gardens – 70%, lawns – 21% and pets – 9%. Phosphorus input was gardens – 81%, lawns – 12% and pets – 7%. Most of the fertiliser applied was organic (64% of nitrogen and 75% of phosphorus by weight).

Kruskal-Wallis non-parametric analyses revealed statistically significant differences with respect to all of the lot characteristics listed above. Medium-sized lots (601–730 m^2) have greater nutrient inputs than both smaller and larger lots (101 kg/ha/year for nitrogen and 26.4 kg/ha/year for phosphorus). New homes ($\leq$ 2 years) apply significantly more nutrients than older homes.

During the past 10 years there appears to have been an increase in the number of dwellings with no native plants in their gardens – a surprising result of this survey.

Future medium-density urban residential developments are expected to have block sizes of 450 to 600 m^2. Residential properties of this size have greater nutrient input rates than the rural land uses that are generally displaced, such as 'beef' and 'mixed grazing', 'horse' and 'lifestyle blocks'.

1 Introduction

The wetlands, rivers and estuaries of Western Australia's Swan Coastal Plain are being adversely impacted by the land uses in their catchments. Excess nutrients reaching the waterways can promote overabundant plant growth in these naturally oligotrophic systems. Nutrient sources include agricultural properties, fertilisers from urban areas, animal and human waste, and industrial discharge. Many estuaries in southern Western Australia suffer from recurrent algal blooms and the associated problems of deoxygenation and fish deaths.

The Swan Coastal Plain's estuaries have suffered continual degradation since European settlement in 1829, with the situation worsening after World War II when cheap phosphatic fertilisers became readily available. Nuisance and toxic algal blooms became such a problem in the Peel Inlet and Harvey Estuary that the Dawesville Cut was constructed. This alleviated the problems in the estuaries but did not improve the condition of the rivers. The Vasse-Wonnerup estuary has the largest nutrient input per catchment area of all the estuaries. Macroalgal and phytoplankton blooms (some the potentially toxic blue-green species) occur in the lower Vasse River, Vasse-Wonnerup estuary and other waterways of the Geographe Bay catchment, such as Toby Inlet. In February 2000, the Swan Estuary was closed to recreation for 12 days because of a bloom of the toxic cyanobacteria *Microcystis aeruginosa*. The bloom was a consequence of large flows and nutrient inputs from the Avon River following cyclonic activity in its catchment. Hardy Inlet has also experienced potentially toxic *Lyngbya* and dinoflagellate blooms in areas of elevated nutrient concentrations.

The Australian Government's Coastal Catchment Initiative (CCI) identified Geographe Bay and the Peel-Harvey, Swan-Canning and Vasse-Wonnerup estuaries as coastal 'hotspots'. Several projects were initiated to develop water quality improvement plans for their catchments, focusing on reducing nutrient losses (nitrogen and phosphorus) from the catchments to the estuaries and ocean.

To determine nutrient inputs to agricultural and urban land uses, these projects included surveys of landholders in rural and urban areas by the Department of Agriculture and Food WA (DAFWA) and the Department of Water.

This *Survey of urban nutrient inputs on the Swan Coastal Plain* (the *urban nutrient survey*) was undertaken in 2006. Its aim was to quantify nutrient inputs for residential urban land on the Swan Coastal Plain, with two broad objectives to determine:

1. the fertilisation practices of householders (the amount, timing of application and type of fertiliser)
2. the amount of nutrient deposited as pet waste (only cats and dogs).

The study area included Perth and regional centres in the state's south.

DAFWA undertook similar surveys of agricultural land uses to determine fertiliser application rates and nutrient inputs in terms of fodder, grain and livestock – thus deducing 'farm-gate' nutrient balances (Ecotones 2004; Ovens et al. 2008; Weaver et al. 2008). The *urban nutrient survey* followed a similar methodology to the agricultural surveys.

The survey results have been and will be used to determine changes in catchment nutrient inputs following land use and management changes. They are also used as input to catchment-nutrient-export models such as the Streamflow Quality Affecting Rivers and Estuaries (SQUARE) model, the Water and Contaminant Analysis and Simulation Tool (WaterCAST) and the Support System for Phosphorus and Nitrogen Decisions (SSPND).

The land-use mapping for these catchment models is at a cadastral scale, thus fertilisation inputs in terms of mass of nitrogen and phosphorus applied to each cadastral parcel of the modelling domain are required. For agricultural land uses, the fertilisation inputs for the surveyed properties are those derived from the rural survey. For properties not surveyed, the fertilisation inputs are estimated from the median values of fertilisation rates (kg/ha/year) of the surveyed properties with similar land use. For residential properties, nutrient inputs are estimated from the median values of the survey data for lots with similar characteristics.

The *urban nutrient survey* was designed to determine nitrogen and phosphorus input rates (kg/ha/year) – including fertiliser and waste from cats and dogs – for urban residential lots with varying characteristics, namely:

- lot size
- age of dwelling
- type of dwelling
- location
- whether occupied by the property owner or lessee.

Although information on whether the surveyed properties were connected to reticulated deep-sewerage or septic tanks was requested, nutrient inputs from septic tanks were not included in analyses (only eight respondents had septic tanks). Similarly, information on water sources (garden bore, rainwater tank or scheme water) was requested, but the nutrient content of the water was not included in analyses.

Previous surveys (Gerritse et al. 1990, 1992; JDA 2002) determined that inputs from detergents and other household chemicals contributed insignificant amounts of nitrogen and phosphorus when compared with inputs from fertilisers and pets, so questions about use of detergents and other household chemicals were not included in the survey. For instance, JDA estimated average nutrient inputs from car washing to be about 0.04 kg/ha/year for nitrogen and 0.14 kg/ha/year for phosphorus.

2 Survey design

Approximately 7000 surveys were delivered to 17 locations (20 suburbs) in Western Australia's Swan-Canning, Geographe Bay and Peel-Harvey catchments (shown in Figures 2.1, 2.2 and 2.3 and listed in Table 2.1). Of these, 1206 surveys were returned – a 17.2% response rate.

The survey was designed to encompass a variety of dwellings, with different characteristics in terms of lot size, age, type, location and occupancy. For example, Mt Hawthorn was chosen because it was likely to have old houses on small lots and Baldivis was chosen because it was likely to have new houses on medium-sized lots. Survey distributors were given instructions (Appendix A) to target the expected type of dwelling in each suburb, starting at one end and delivering to all target homes until there were no surveys left. The targeted lot sizes, dwelling types and ages for each location (suburb) are listed in Table 2.1. The lot size and age categories, derived from the returned surveys, are listed in Table 2.2 and Table 2.3 respectively.

An example of a completed survey is included in Appendix B.

2.1 Questionnaire design

The questionnaire consisted of 19 questions in three sections. The first section was titled 'About your property'. It asked for information on the property's lot size, dwelling age, dwelling type, suburb and if the respondent was the owner or renter (covering the five independent variables investigated in this study). Other information was also collected on the number and type of pets on the property and pet waste disposal. The second section, 'Gardens and lawns', investigated the percentage area of lawn and garden, types of plants, garden/lawn maintenance and waste disposal. The final section, 'Watering and fertilisers', asked about water sources, methods of watering, watering times, and the amounts and seasonal timing of fertilisation. The survey was four pages long. A completed survey is included in Appendix B.

The problems encountered with interpreting the survey responses and suggestions for avoiding them in future surveys are discussed in Section 5.4.

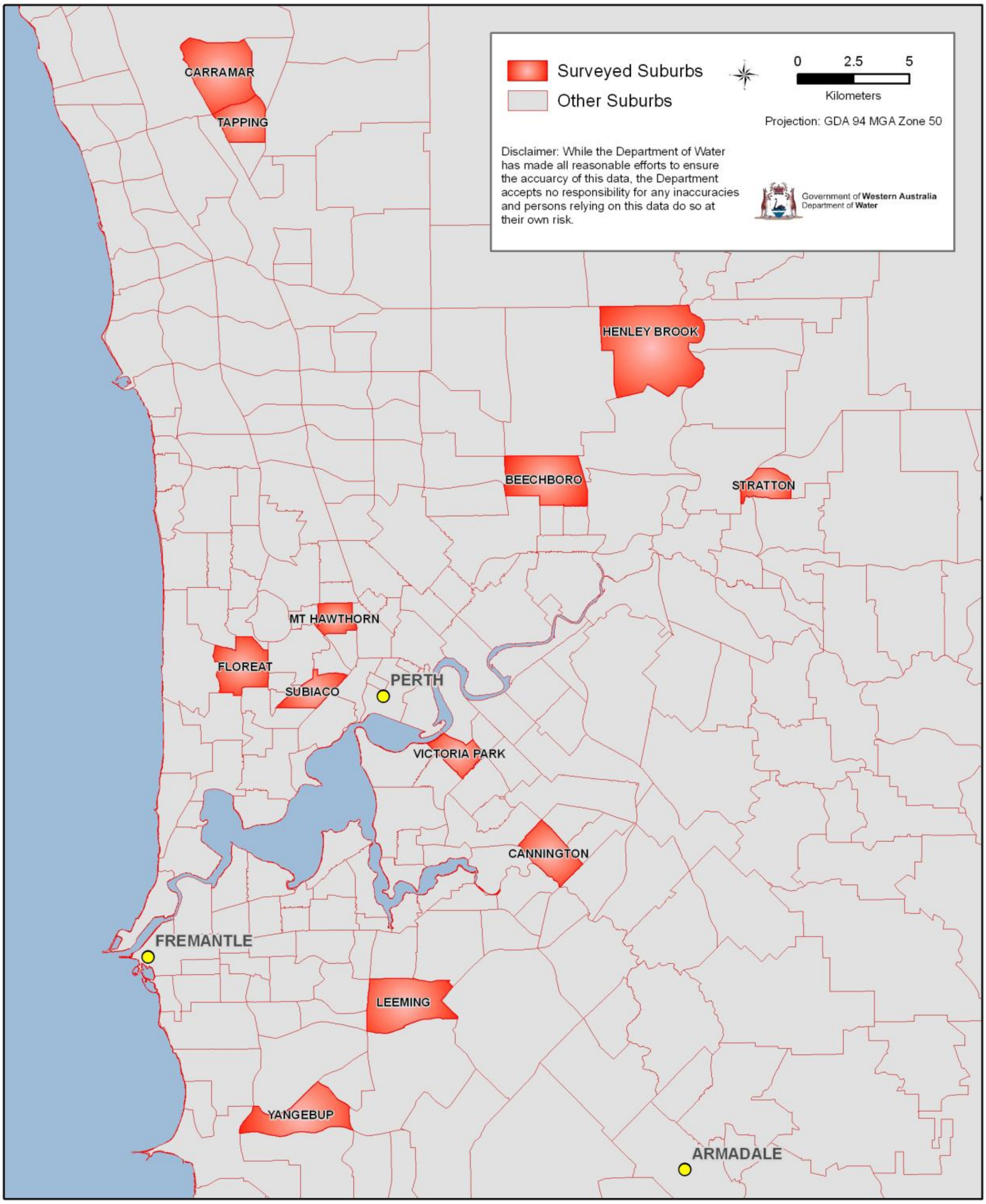


Figure 2.1 Distribution of survey – Perth metropolitan area

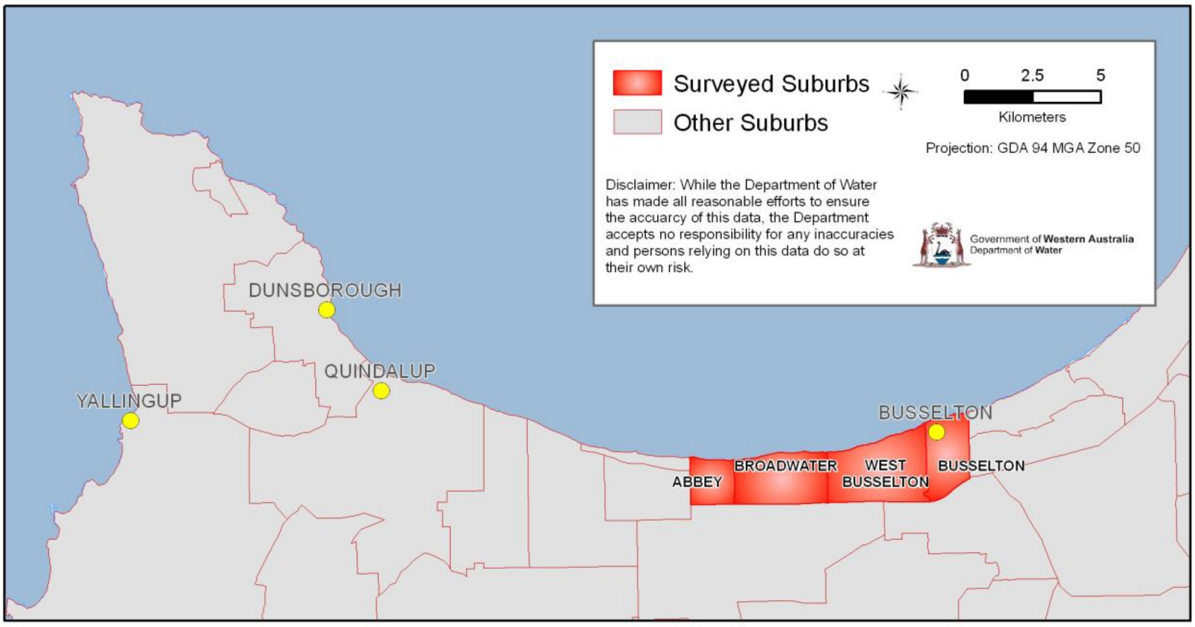


Figure 2.2 Distribution of survey – Geographe Bay region

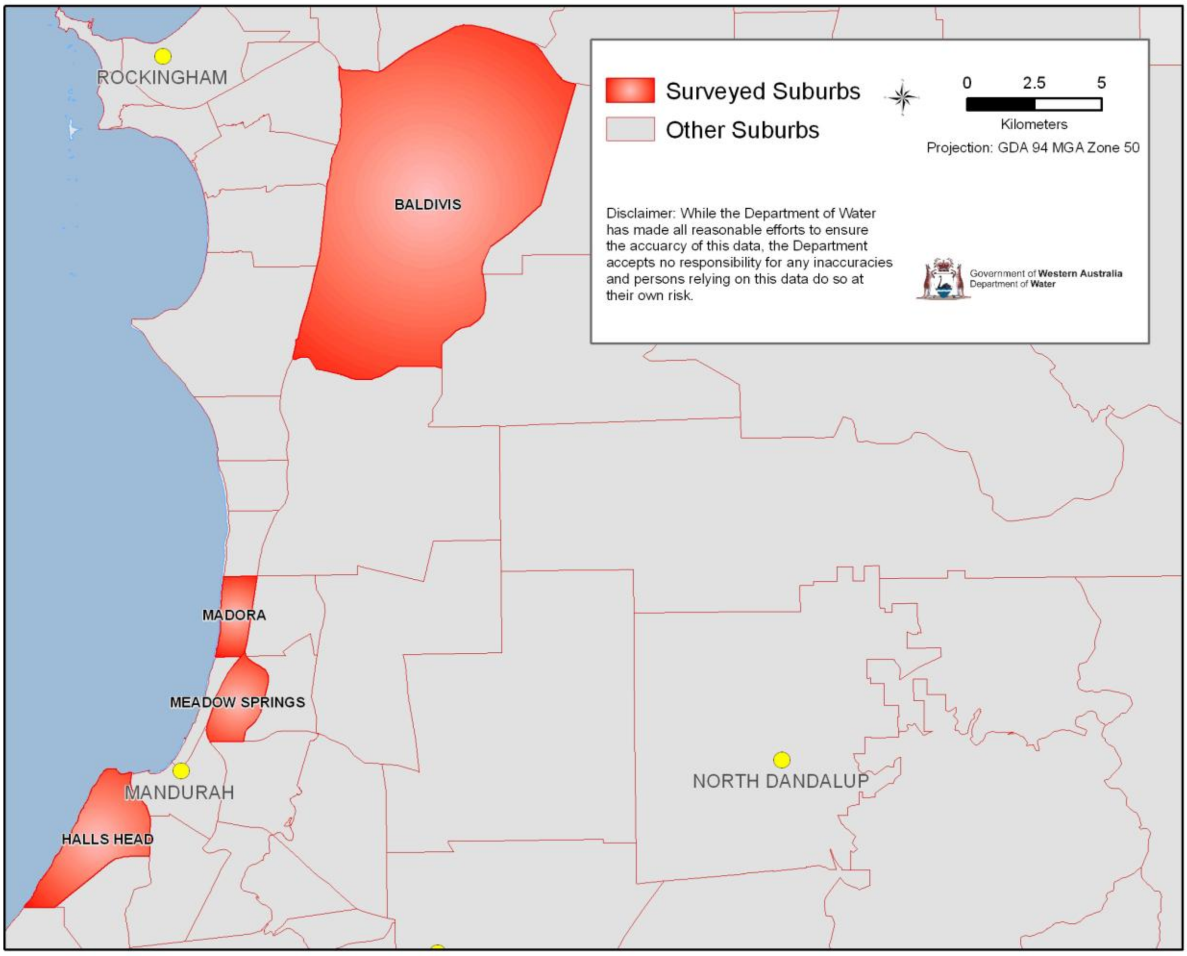


Figure 2.3 Distribution of survey – Peel region

Table 2.1 Suburbs and characteristics surveyed

Suburb	Dwelling type	Age	Lot size
Swan-Canning			
Beechboro	House	New & recent	Small
Cannington	House/villa	New & recent	Small
Floreat	House	Old	Large
Henley Brook	House	Recent	Small & medium
Leeming	House	Old	Medium
Mt Hawthorn	House	Old	Small
Stratton	House	Old & established	Small
Subiaco	Townhouse	Recent	Small
Subiaco	House	Established	Small
Tapping/Carramar	House	Established	Small & medium
Tapping/Carramar	House	Recent	Small & medium
Victoria Park	Villas/units	Old & established	Small
Yangebup	House	Old	Medium
Peel-Harvey			
Baldivis	House	New	Small & medium
Baldivis	House	Recent	Medium
Halls Head	Canal	Any	Any
Meadow Springs/Madora Bay	House	New & recent	Medium
Meadow Springs/Madora Bay	House	Established	Medium
Geographe Bay			
Abbey Waters/Broadwater	House	New & recent	Small & medium
Busselton	House	Old	Large
West Busselton	House	Old & established	Medium

Table 2.2 Lot size categories ('bins')

Area category	Area
Very small	$\leq$ 400 m^2
Small	401–600 m^2
Medium	601–730 m^2
Large	> 730 m^2

Table 2.3 Dwelling age categories

House age description	Age categories
Brand new	< 12 months
New	1–2 years
Recent	3–5 years
Established	6–10 years
Old	> 10 years

3 Analyses

3.1 Description of the dataset

The survey responses were used to determine nitrogen and phosphorus input (kg) and input rates (kg/ha/year) from fertilisers and pet wastes to residential lots.

The final dataset contains 1206 records where one row corresponds to the responses of one survey respondent. Of these 1206 respondents, 936 (78%) provided answers on the amount and type of fertilisers they used, allowing their responses to be included in the analyses. The other 270 records were not included in the analyses because even though these respondents said they used fertiliser, they either skipped or answered ‘don’t know’ to the final question on the amount and type of fertiliser, regardless of whether they had pets. The number of surveys from each location that were used in the analyses is given in Table 3.1.

Table 3.1 Number of surveys used in statistical analyses

Location	**Number of surveys used in analyses**
Abbey Waters/Broadwater	18
Baldivis	78
Beechboro	62
Busselton	67
Cannington	18
Floreat	115
Halls Head	81
Henley Brook	44
Leeming	98
Meadow Springs/Madora Bay	60
Mt Hawthorn	77
Stratton	35
Subiaco	33
Tapping / Carramar	58
Victoria Park	34
West Busselton	25
Yangebup	33
Total	936

3.2 Estimation of nutrient input

Nitrogen and phosphorus inputs from fertiliser use were determined for each respondent. The respondents indicated the types of fertilisers used; the timing and frequency of use; and the amount used for each application. Timing was specified in terms of seasons, which enabled a seasonal breakdown of the data. In order to determine the amount used, respondents indicated the size and number of bags, sacks or trailer loads used for each application.

To determine the nitrogen and phosphorus inputs, information on the nutrient content and bulk density of each fertiliser (Appendix C) was obtained and the mass of nitrogen and phosphorus in each ‘small bag’, ‘large bag’, ‘sack’ or ‘trailer’ for each fertiliser type was determined. Some assumptions were used in the calculations. The volume of a trailer was estimated to be 0.69 m^3 (4 ft x 6 ft x 30 cm depth) and the volume of a sack was estimated to be 0.25 m^3 (1 m x 0.5 m x 0.5 m). When no information on a particular fertiliser was available, information from a similar fertiliser was used. Many respondents used more than one type of fertiliser on their lawns and gardens. As a result, the cumulative mass of nitrogen and phosphorus for all fertiliser applications was determined for each respondent for each season.

Average annual quantities of nutrients in dog and cat excreta, from Gerritse et al. (1992), are given in Table 3.2. Respondents indicated the proportion of pet waste disposed of on-property as either ‘all’ (100%), ‘most’ (75%), ‘some’ (25%) or ‘none’ (0%). Thus nitrogen and phosphorus inputs from pet wastes were calculated from the number and type of pets, the estimated annual inputs for the pets and the portion of the waste disposed of on-property. Seasonal contributions were taken as a quarter of the annual contributions.

Table 3.2 Average amount of nitrogen and phosphorus produced per animal per year (Gerritse et al. 1992)

	Nitrogen (kg)	Phosphorus (kg)
Dog	5.5	1.37
Cat	0.88	0.22

Although a variety of animals besides cats and dogs were kept as pets, including birds, ducks, poultry, ferrets, guinea pigs, rabbits, crabs and horses, their numbers were minimal. Only 16 properties had poultry (46 birds in total), while two had horses (one horse each) and another had six ducks. Hence the nutrient inputs from animals other than cats and dogs were not included in the analyses.

Annual nutrient inputs for each respondent were the sum of their contributions from fertiliser and pets (cats and dogs). Input rates were then determined by dividing by lot size as displayed in Equation (1).

(1)

$$R_r = \frac{F_r + P_r}{A_r}$$

Where:

R_r = annual nutrient input rate for each respondent (i.e. nutrient input rate for cadastral parcel) (kg/ha/year)

F_r = annual mass (kg) of fertiliser applied by respondent

P_r = annual mass (kg) of pet waste disposed of on the respondent’s lot

A_r = respondent’s lot area (ha).

Input rates were used in the statistical analyses, not total input mass. Total inputs would generally increase with lot size because people would have larger areas of garden and lawn on larger blocks. However, it was expected that nutrient input rates would also vary with lot size. It was postulated that people with small blocks have little opportunity to fertilise because the dwelling and car parking takes up most of the area; people with medium-sized blocks have well-tended lawns and gardens; and people with large blocks, although they generally have a larger proportion of their block as lawn and gardens, tend not to have the resources to tend their lots as intensively as those with medium-sized blocks. Thus, it was expected that medium-sized lots would have greater nutrient input rates than both smaller and larger lots.

3.3 Data analyses

Rigorous statistical analyses were undertaken to determine statistically significant differences in nitrogen and phosphorus input rates (including fertilisation and pet waste) (kg/ha/year) between properties with varying characteristics (lot size, dwelling age, dwelling type, location and occupancy). Statistical analyses were not done on other characteristics of the properties, such as the timing of fertiliser application, type of fertiliser applied, number of pets and disposal of pet wastes, and types of garden. These descriptive data are presented in Section 4.2 and the results of the statistical analyses are in Section 4.3.

The lot size and age categories used for the statistical analyses are listed in Table 2.2 and Table 2.3 respectively. The locations are listed in Table 2.1. Nutrient inputs from pets other than cats and dogs, septic tanks and watering from garden bores were not included. Garden and lawn waste disposal was not considered.

Kruskal-Wallis non-parametric analysis was chosen as the statistical test most appropriate because of the non-normality of the data. The Kruskal-Wallis analysis of variance (ANOVA) tests equality of population medians among groups. It is analogous to the one-way ANOVA but it makes no assumptions about the distribution of data. It cannot test the significance of interactions between groups (Kruskal & Wallis 1952; Helsel & Hirsch 1992).

The Kruskal-Wallis ANOVA significance test returns a *p-value* for the significance of the difference between at least two of the median values. The Matlab™ <www.mathworks.com.au> 'multcompare' function was then used to determine which of the populations were statistically different to each other. As an example, Appendix D contains the outputs from the 'multcompare' function for nitrogen input rates with respect to lot size.

Medians and 25th and 75th percentiles of the input rates are provided as robust locations of centrality and spread estimates of the data.

4 Results

4.1 Summary of all data

Of the 936 records used for analyses, 99 (11%) contained values of zero for nitrogen and phosphorus inputs: these were respondents who didn't fertilise their gardens or have pets.

The median input rate of nitrogen from fertilisers and pets is 84.1 kg/ha/year, with 25th and 75th percentiles being 19.5 and 207 kg/ha/year respectively. Of this total amount of nitrogen, 91% was applied as fertiliser (of which 64% was organic) and 9% as pet waste. The median input rate of phosphorus from fertilisers and pets is 19.7 kg/ha/year, with 25th and 75th percentiles being 5.1 and 57.7 kg/ha/year respectively. Of the total amount of phosphorus, 93% was applied as fertiliser (of which 75% was organic) and 7% as pet waste. Statistics for nitrogen and phosphorus input rates are given in Table 4.1.

Table 4.1 Total (from pets and fertilisers) nitrogen and phosphorus input rate statistics

	Nitrogen input rate (kg/ha/year)	Phosphorus input rate (kg/ha/year)
# of data	936	936
# of zero values	99	116
25th percentile	19.5	5.1
Median	84.1	19.7
75th percentile	207	57.7
Maximum value	10 680	3737
Average	208	72.0

There were several unexpectedly large values of nitrogen and phosphorus input. Twelve properties had estimated nitrogen input rates greater than 1800 kg/ha/year and 13 properties had estimated phosphorus input rates greater than 700 kg/ha/year. These input rates are greater than intensive agricultural land uses such as annual horticulture – which have inputs estimated at 143 kg/ha/year of nitrogen and 127 kg/ha/year of phosphorus – and piggeries – which have inputs estimated at 629 kg/ha/year of nitrogen and 145 kg/ha/year of phosphorus (see Section 5.3).

4.2 Type of nutrient application

4.2.1 Water source

Nutrient input from water was not included in the analyses. The high nutrient content of bore water is due to past fertilisation, so including this water as a nutrient input would have meant fertiliser in the groundwater was included twice. On average, 32% of the respondents used bore water for watering. Floreat had the greatest bore usage, with 67% of the respondents watering with bore water.

4.2.2 Garden, lawns and pets

Table 4.2 shows nitrogen and phosphorus inputs due to fertilisation of lawn and garden areas and pet waste. Garden fertiliser accounted for most nutrient input: 70% of nitrogen and 81% of phosphorus. Pet waste contributed 9% of the nitrogen input and 7% of the phosphorus input. Note that these percentages relate to the total mass of pet and fertiliser application and not to the average input rates displayed in Table 4.4 and Table 4.5.

Table 4.2 Percentage contributions (by weight) of nitrogen and phosphorus from garden, lawn and pets

	Nitrogen (%)	**Phosphorus (%)**
Garden	70	81
Lawn	21	12
Pets	9	7

In total, 84 different types of fertilisers were used on lawn and garden areas. The fertiliser types are listed in Appendix C. While there was a greater number of commercial (inorganic) fertilisers used (74%) than organic fertilisers (26%), a larger proportion of the nutrient inputs (by weight) were from organic sources – 64% of nitrogen and 75% of phosphorus – as shown in Table 4.3.

Table 4.3 Breakdown of organic and commercial fertiliser inputs by weight (kg)

Fertiliser type	**Nitrogen**	**Phosphorus**
Organic	64%	75%
Inorganic (commercial)	36%	25%

4.2.3 Pet waste

The median values for the nitrogen and phosphorus pet-waste input rates for the whole dataset, and for data related to the different lot sizes, are all zero. This merely indicates that most people don't have pets. The average values of pet-waste input rates for different lot sizes and the 75th percentiles are given in Table 4.4. For comparison, the average total nutrient input rates (pet waste plus fertiliser) are given in Table 4.5.

Clearly the data for pet nutrient input rates are very skewed, as the averages for most lot sizes ('very small', 'small' and 'medium') are greater than the 75th percentiles. The data for total nutrient input rates are also skewed, with averages for phosphorus input rates being greater than the 75th percentiles in all cases, and average nitrogen input rates being greater that the 75th percentiles for 'very small' and 'small' lots.

Differences are apparent in the pet nutrient input rates for 'very small' lots compared with the larger lots. However, statistical analyses were only undertaken for total nutrient input rates (pet waste plus fertiliser), which are presented in the next section.

Table 4.4 Average and 25th and 75th percentiles for nutrient input rates from pets

		Nitrogen input rate (kg/ha/year)		Phosphorus input rate (kg/ha/year)	
Lot size	Sample size	Average	75th percentile	Average	75th percentile
Very small	70	15.2	0	3.8	0
Small	267	21.8	17.7	5.4	4.4
Medium	268	19.7	19.6	4.9	4.9
Large	331	18.2	19.5	4.6	4.9
All lots	936	19.4	19.6	4.9	4.9

Table 4.5 Average, median and 25th and 75th percentiles for nutrient input rates from pets and fertiliser

		Nitrogen input rate (kg/ha/year)			
Lot size	Sample size	Average	25th percentile	Median	75th percentile
Very small	70	189	0	23.4	98.2
Small	267	253	22.4	91.2	244
Medium	268	210	33.3	101	228
Large	331	174	16.4	74.2	180
All lots	936	208	19.5	84.1	207
		Phosphorus input rate (kg/ha/year)			
Lot size	Sample size	Average	25th percentile	Median	75th percentile
Very small	70	67.6	0	6.9	29.5
Small	267	83.6	6.1	22.8	63.0
Medium	268	78.8	9.5	26.4	59.5
Large	331	58.2	4.0	18.0	53.7
All lots	936	72.0	5.1	19.7	57.7

4.2.4 Seasonality of fertiliser application

The seasonality of the organic and commercial (inorganic) inputs for nitrogen and phosphorus fertilisation is shown in Figure 4.1 and listed in Table 4.6. Although there is great variability between respondents on the timing of fertiliser application, the greatest proportion of fertiliser was applied in spring, which is the start of the growing season (46% for both nitrogen and phosphorus), and lesser amounts were applied in the subsequent seasons.

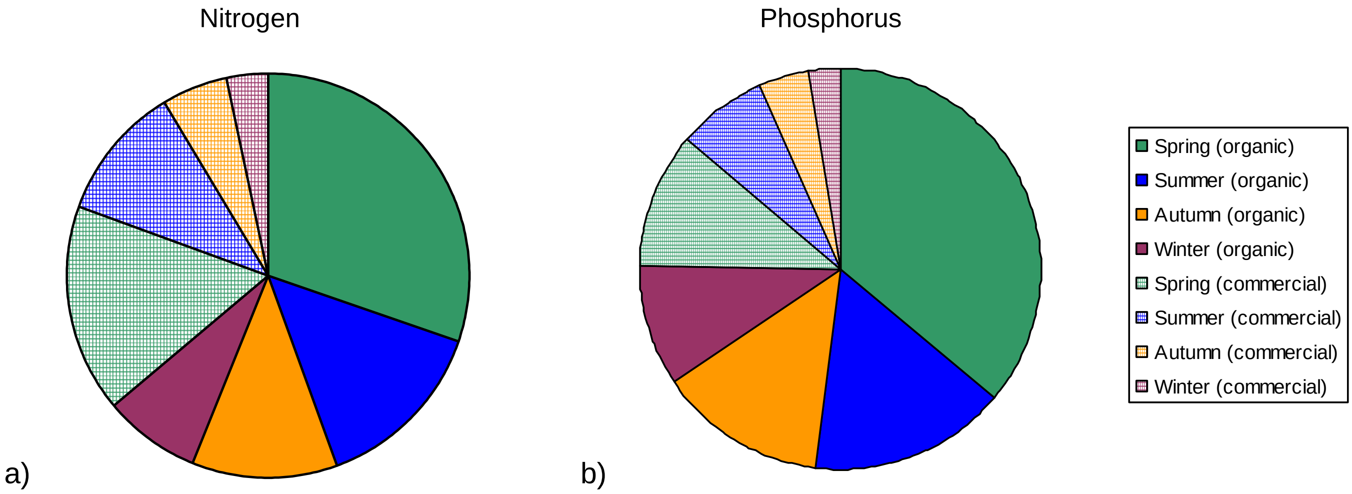


Figure 4.1 Percentage contributions (by weight) of fertiliser nutrient inputs for a) nitrogen and b) phosphorus in terms of both seasonality and fertiliser type (organic/commercial)

Table 4.6 Percentage of nitrogen and phosphorus fertiliser input by weight for seasons

	Nitrogen			**Phosphorus**		
	Organic (%)	**Commercial (%)**	**Total (%)**	**Organic (%)**	**Commercial (%)**	**Total (%)**
Spring	30	17	46	36	11	46
Summer	14	11	25	16	7	23
Autumn	12	5	17	14	4	18
Winter	8	3	11	10	3	13
Annual	64	36	100	75	25	100

Some suburbs showed similarities in terms of seasonal input rates. These were suburbs of similar age, lot size, and lawn and garden area (e.g. Baldivis and Tapping/Carramar; Floreat and Busselton). In some cases, the seasonal input rates were similar only for nitrogen (e.g. Meadow Springs/Madora Bay and Tapping/Carramar). Meadow Springs/Madora Bay and Tapping/Carramar have similar lawn areas (explaining similar nitrogen applications), but different garden areas.

4.2.5 Native gardens

The survey requested information on what percentage of the garden was devoted to native plants and low water usage. Because differences were apparent in the native vegetation plantings for properties of different ages, the data were grouped into two classes: those less than or equal to 10 years old, and those greater than 10 years old. There were approximately the same number of data in each group, but in order to make comparisons, the data in the older group were standardised, as shown in Table 4.7. The data for percentage area of native plantings in each age grouping are plotted in Figure 4.2.

The statistics indicate that 15% of the dwellings older than 10 years have no native plants, whereas for dwellings 10 years old or less, 25% have no native plants. This tendency towards fewer native plantings in younger dwellings was a surprising result of the survey.

Table 4.7 Number of properties with different percentage areas of native gardens

	Dwellings ≤ 10 years old	Dwellings > 10 years old	
Percent native plantings	**Number of properties**	**Number of properties**	**Standardised number of properties[1]**
0	143	80	87
1 - 10	93	117	127
11 - 20	50	55	60
21 - 30	47	48	52
31 - 40	30	27	29
41 - 50	72	62	67
51 - 60	19	36	39
61 - 70	18	25	27
71 - 80	40	33	36
81 - 90	22	14	15
91 - 100	28	20	22
Total	562	517	562

[1] *No. of properties * 562/517*

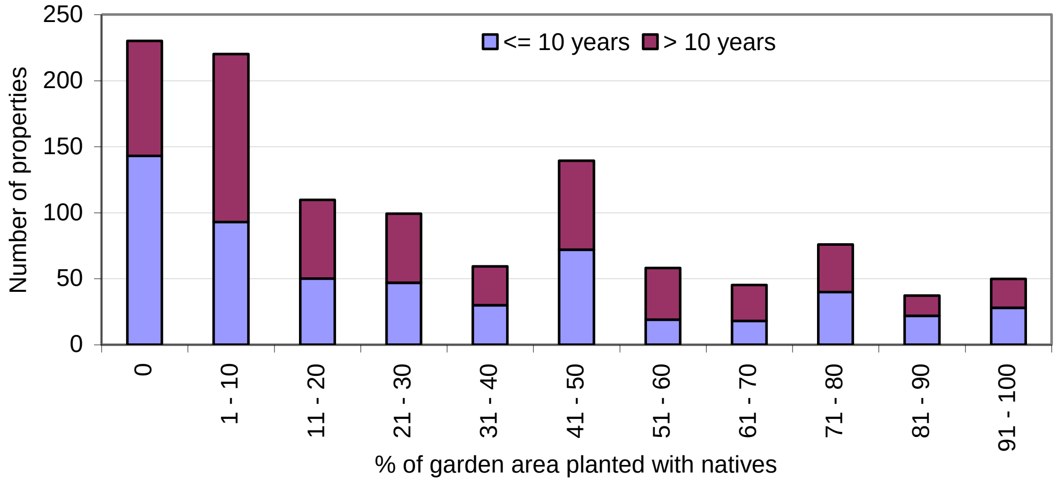


Figure 4.2 Number of properties with native plants as a percentage of total garden. The numbers for dwellings of ≤ 10 years old are the actual numbers. For dwellings > 10 years old the numbers have been adjusted for the unequal sample sizes between the two age categories (Table 4.7)

4.3 Results of statistical analyses

Statistical analyses were done to calculate the differences in nitrogen and phosphorus input rates (kg/ha/year) to lots, using the independent variables of:

- lot size
- dwelling age
- dwelling type
- locations (suburb)
- occupancy (owner or renter).

The lot size and age categories are listed in Table 2.2 and Table 2.3 respectively; the locations are listed in Table 2.1. The input rates include fertiliser and pet waste from cats and dogs. Nutrient inputs from septic tanks and water from garden bores were not included. Garden and lawn waste disposal was not considered.

Kruskal-Wallis ANOVA tests revealed statistically significant differences in nitrogen and phosphorus input rates for all of the independent variables. The analyses for each of the variables are presented in the subsequent sections. Medians and 25th and 75th percentiles of the input rates are provided as robust locations of centrality and spread estimates of the data. Box plot graphs of the data were done in Matlab™. The red line represents the median value, and the box the 25th and 75th percentiles. Outliers (values less than the 25th percentile or greater than the 75th percentile) are represented by blue circles.

4.3.1 Lot size

Figure 4.3 and Figure 4.4 contain plots of nitrogen and phosphorus input rates (kg/ha/year) against block size. The properties surveyed ranged in size from 100 to 6900 m^2. There were 12 properties that estimated nitrogen input rates of more than 1800 kg/ha/year and 13 properties that estimated phosphorus input rates greater than 700 kg/ha/year, which are not displayed on the graphs.

The nitrogen and phosphorus input rates are also plotted on a log scale (zero values have been given the value of 0.1 kg/ha/year) in Figure 4.5 and Figure 4.6 respectively, so that the spread of the data and the number of zero values can be seen.

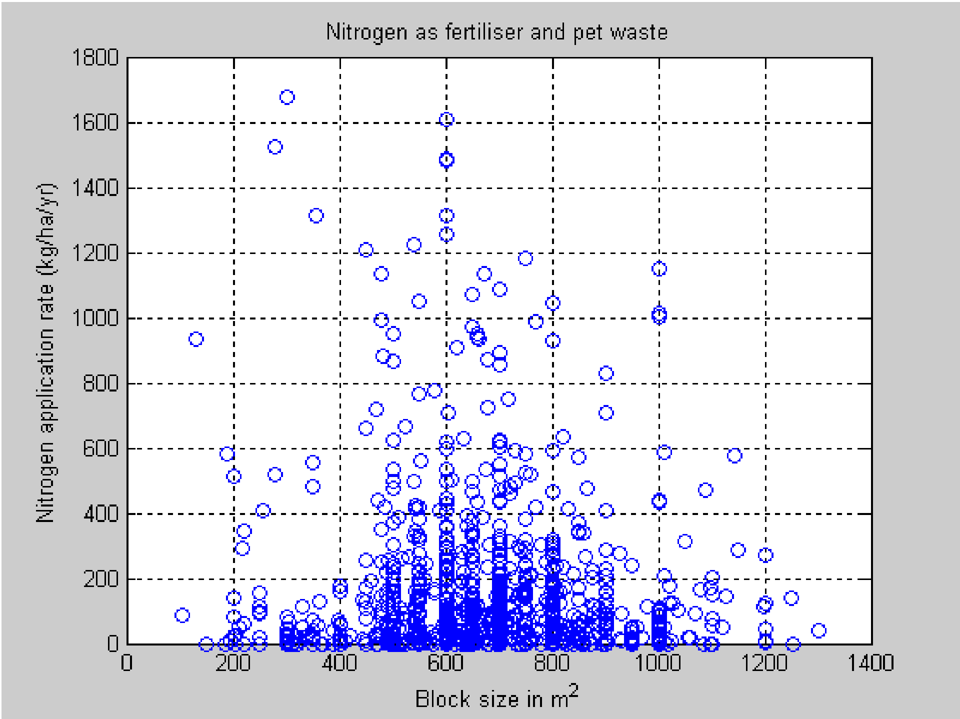


Figure 4.3 Scatter plot of nitrogen input rate against block size

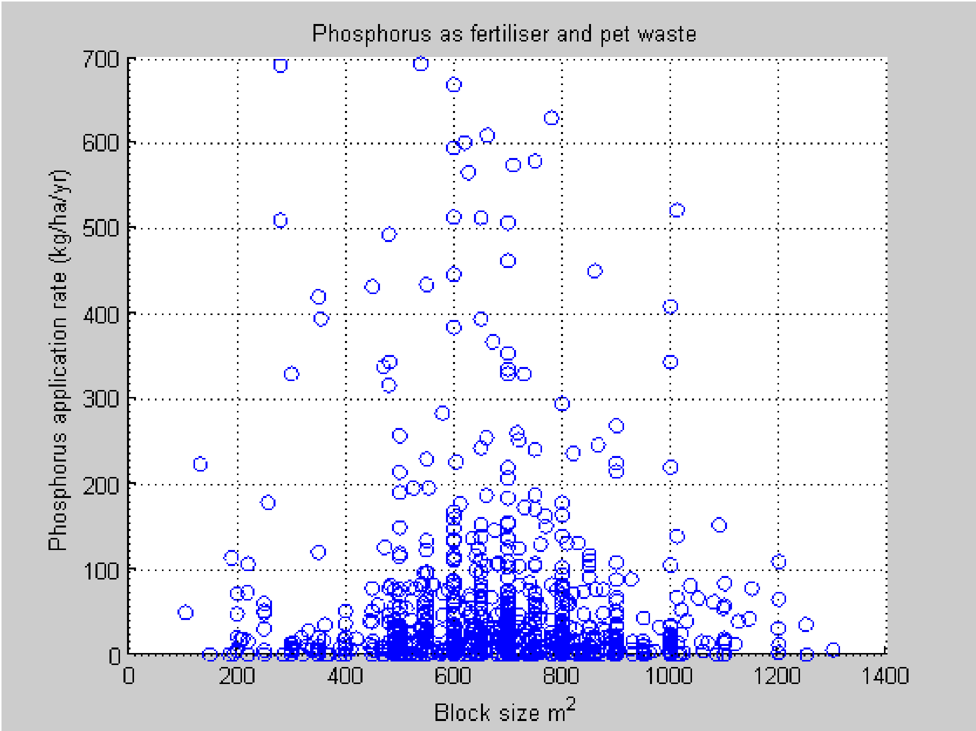


Figure 4.4 Scatter plot of phosphorus input rate against block size

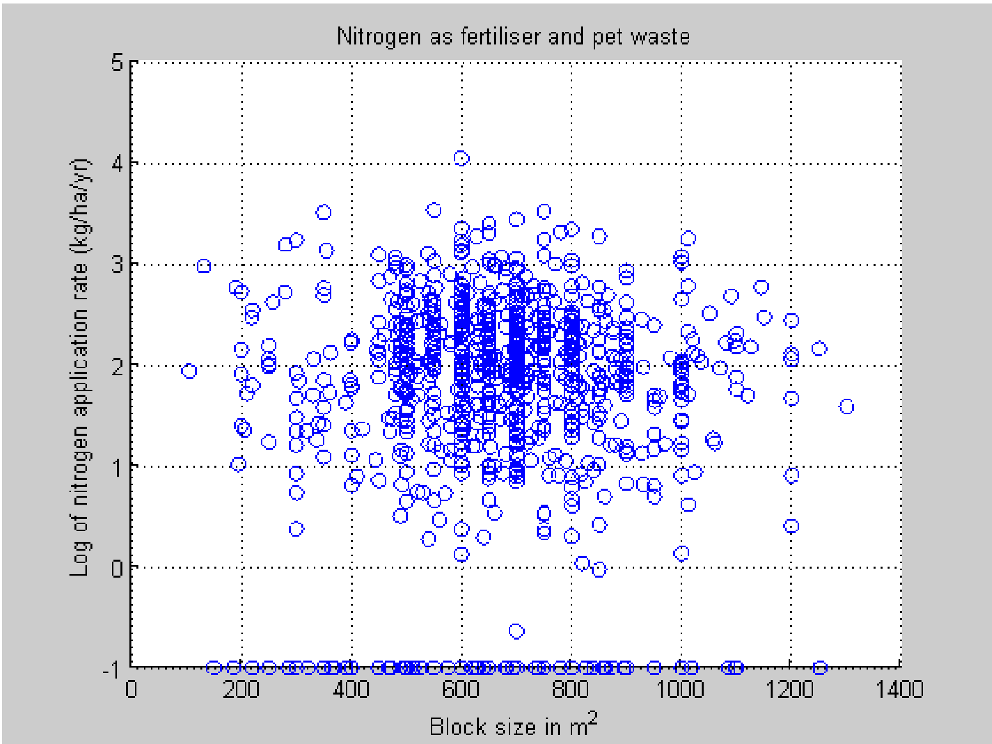


Figure 4.5 Log (base 10) of nitrogen input rate against block size (zero values have been given a value of 0.1 kg/ha/year)

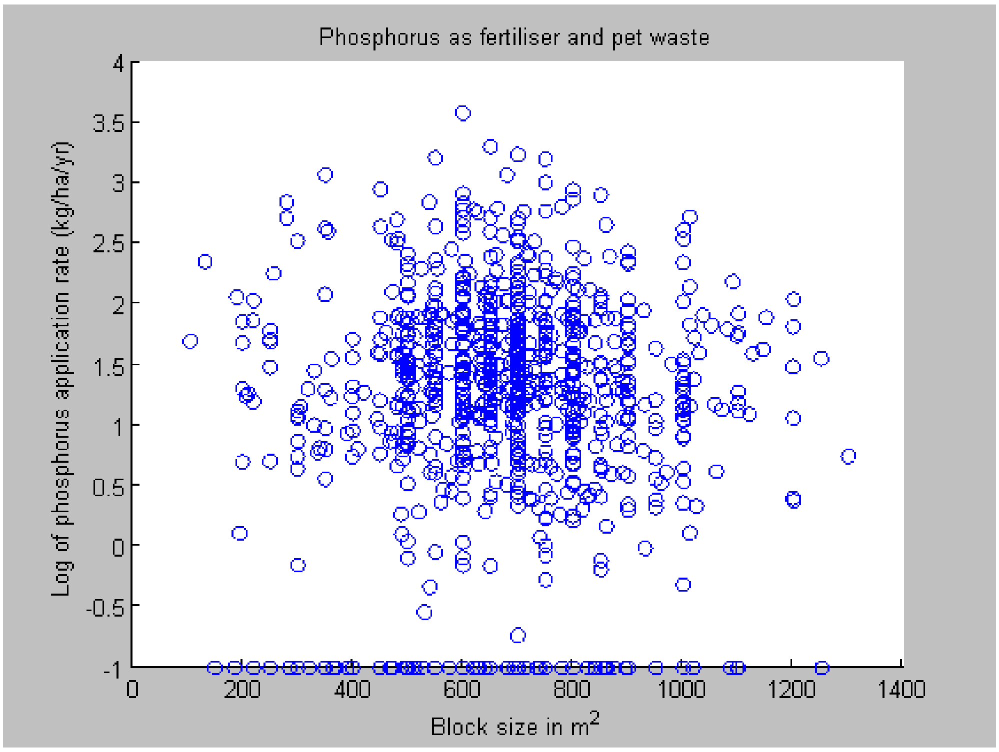
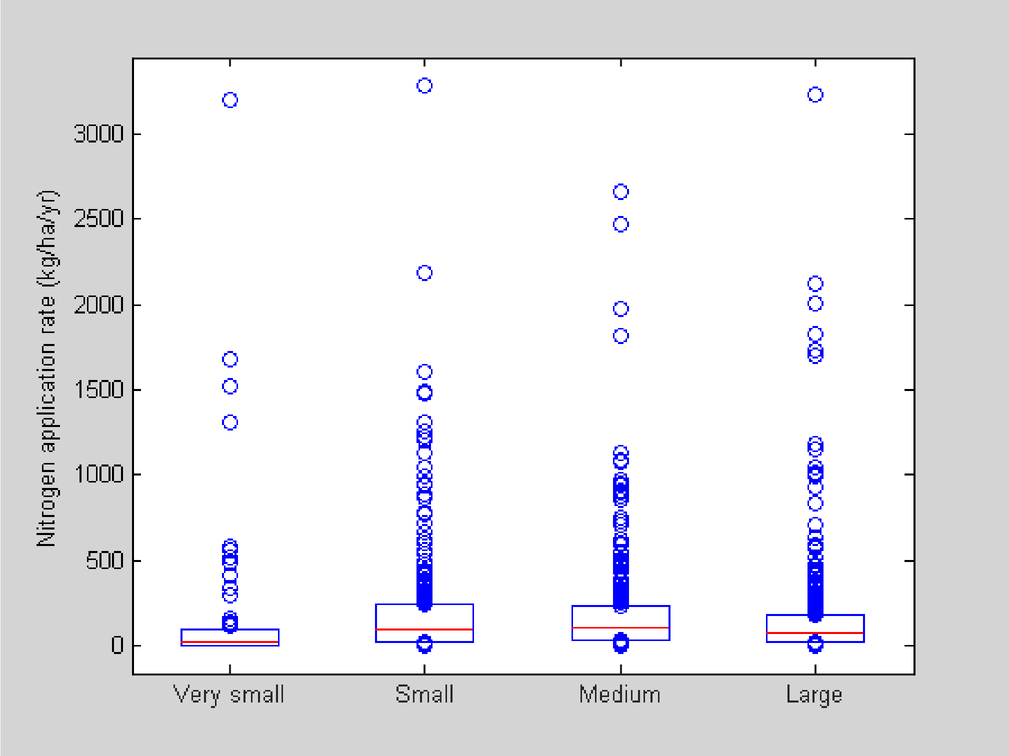


Figure 4.6 Log (base 10) of phosphorus input rate against block size (zero values have been given a value of 0.1 kg/ha/year)

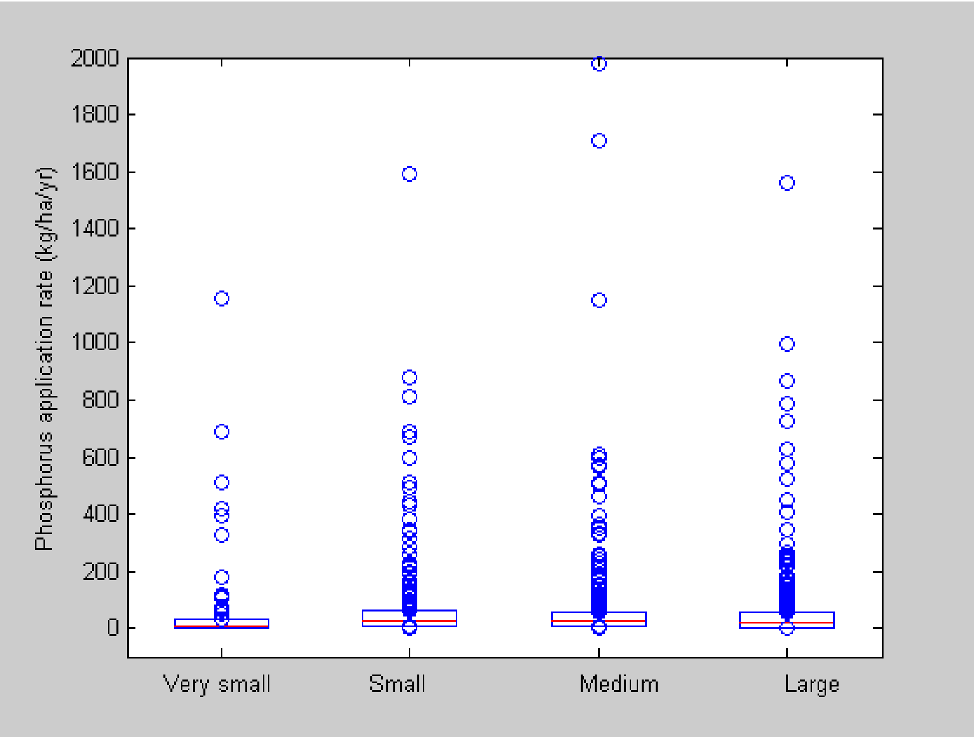
The data were 'binned' by the lot area as listed in Table 2.2. The nitrogen and phosphorus input rates are plotted against the lot area 'bins' in Figure 4.7 and Figure 4.8 respectively. The median input rates and 25th and 75th percentiles for each block-size class for nitrogen and phosphorus are given in Table 4.8 and Table 4.9 respectively.

The data have a large range and are skewed with average values generally being greater than the 75th percentiles, except for the nitrogen input rate on 'medium' and 'large' lots (Table 4.5).



**Outlier removed for visual clarity; database ID 155 was a new, owner-occupied house on a small block in Beechboro, total nitrogen 10 680 kg/ha/yr.*

Figure 4.7 Nitrogen input rate (fertilisers and pet waste) by block-size class



Outlier removed for visual clarity; database ID 155 was a new, owner-occupied house on a small block in Beechboro, total phosphorus 3737 kg/ha/yr.

Figure 4.8 Phosphorus input rate (fertilisers and pet waste) by block-size class

Table 4.8 Nitrogen input rate medians and 25th and 75th percentiles for each block-size class

		Nitrogen input rate (kg/ha/year)			
Lot-size class	Area (m^2)	25th percentile	Median	75th percentile	Sample size
Very small	≤ 400	0	23.4	98.2	70
Small	401–600	22.4	91.2	244	267
Medium	601–730	33.3	101	228	268
Large	> 730	16.4	74.2	180	331
All lots		19.5	84.1	207	936

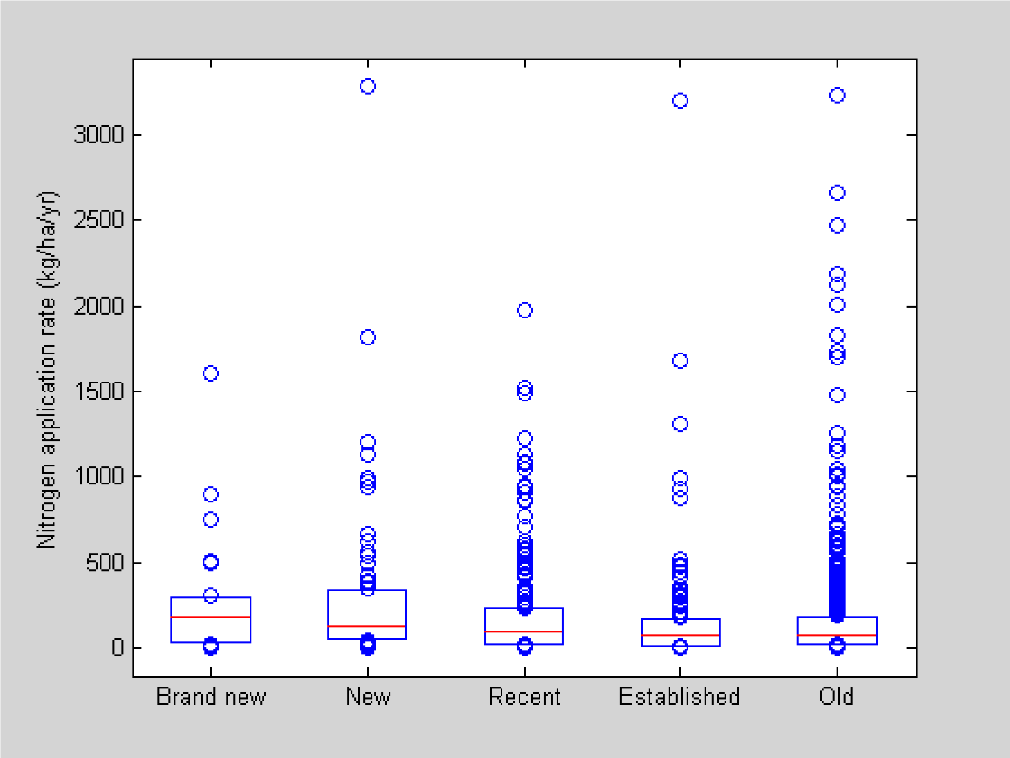
Table 4.9 Phosphorus input rate medians and 25th and 75th percentiles for each block-size class

		Phosphorus input (kg/ha/yr)			
Lot-size class	Area (m^2)	25th percentile	Median	75th percentile	Sample size
Very small	≤ 400	0	6.9	29.5	70
Small	401–600	6.1	22.8	63.0	267
Medium	601–730	9.5	26.4	59.5	268
Large	> 730	4	18.0	53.7	331
All lots		5.1	19.7	57.7	936

Size of urban block was found to be a determining factor for the amount of nitrogen and phosphorus applied to the land. Kruskal-Wallis one-way ANOVAs revealed significant differences in application rate depending on the size of block; for both nitrogen and phosphorus, $p < 0.0001$. Medium-sized blocks had the most nutrients in terms of kg/ha of nitrogen and phosphorus applied, and then in descending order of ‘small’, ‘large’ and ‘very small’ blocks. All differences were significant apart from ‘small’, which was not significantly different to either ‘medium’ or ‘large’.

4.3.2 Age of dwelling

The data were ‘binned’ into the age classes listed in Table 2.3. The nitrogen input rates are plotted against dwelling age in Figure 4.9 and the medians and 25th and 75th percentiles for each age class are given in Table 4.10. Similarly the phosphorus plot is in Figure 4.10 and the statistics are in Table 4.11.



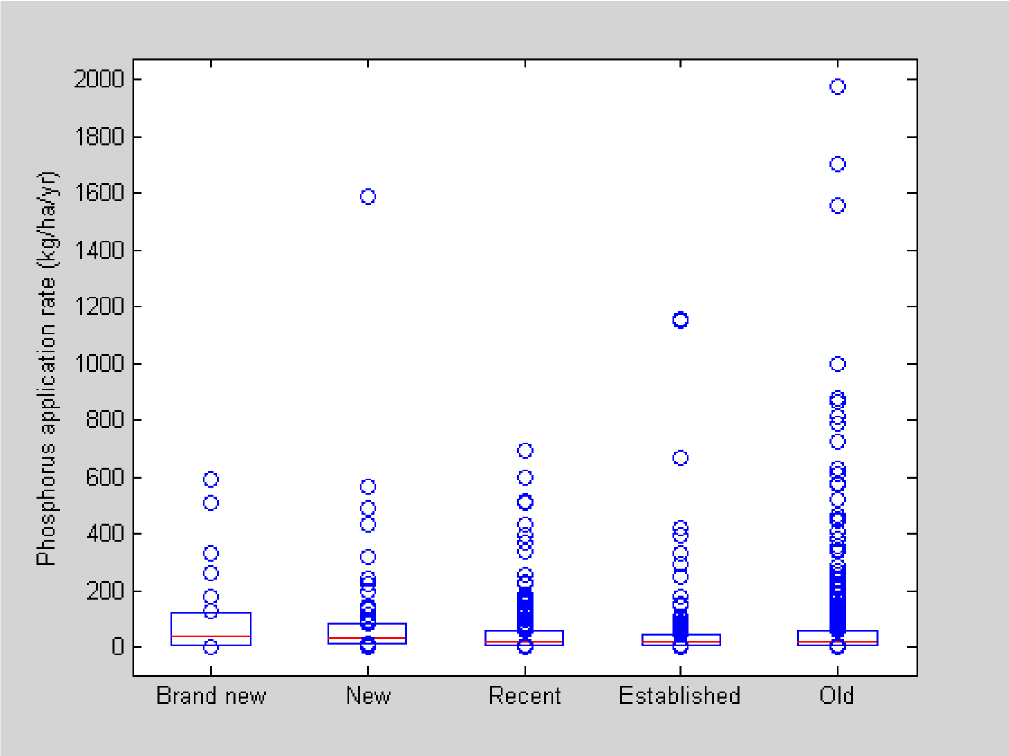
Outlier removed for visual clarity; database ID 155 was a new, owner-occupied house on a small block in Beechboro, total nitrogen 10 680 kg/ha/year.

Figure 4.9 Nitrogen input rates (fertilisers and pet waste) by dwelling age

Table 4.10 Nitrogen input rate medians and 25th and 75th percentiles by dwelling age

Age class	Age (years)	Nitrogen input rate (kg/ha/year)			Sample size
		25th percentile	Median	75th percentile	
Brand new	<1	44.8	177	282	23
New	0–2	52.4	132	344	69
Recent	3–5	23.7	91.3	225	256
Established	6–10	11.0	71.3	168	120
Old	>11	16.6	75.0	182	467
All lots		19.5	84.1	207	935

Note: there was a property which did not provide age, thus not used in age analyses



Outlier removed for visual clarity; database ID 155 was a new, owner-occupied house on a small block in Beechboro, total phosphorus 3737 kg/ha/year.

Figure 4.10 Phosphorus input rates (fertilisers and pet waste) by dwelling age

Table 4.11 Phosphorus input rate medians and 25th and 75th percentiles by dwelling age

Age class	Age (years)	Phosphorus input rate (kg/ha/yr) 25th percentile	Median	75th percentile	Sample Size
Brand new	<1	7.0	39.1	116	23
New	0 – 2	15.9	33.3	82.0	69
Recent	3 – 5	5.1	21.5	53.8	256
Established	6 – 10	4.4	17.6	46.2	120
Old	>11	4.5	18.5	55.0	467
All lots		5.1	19.7	57.7	935

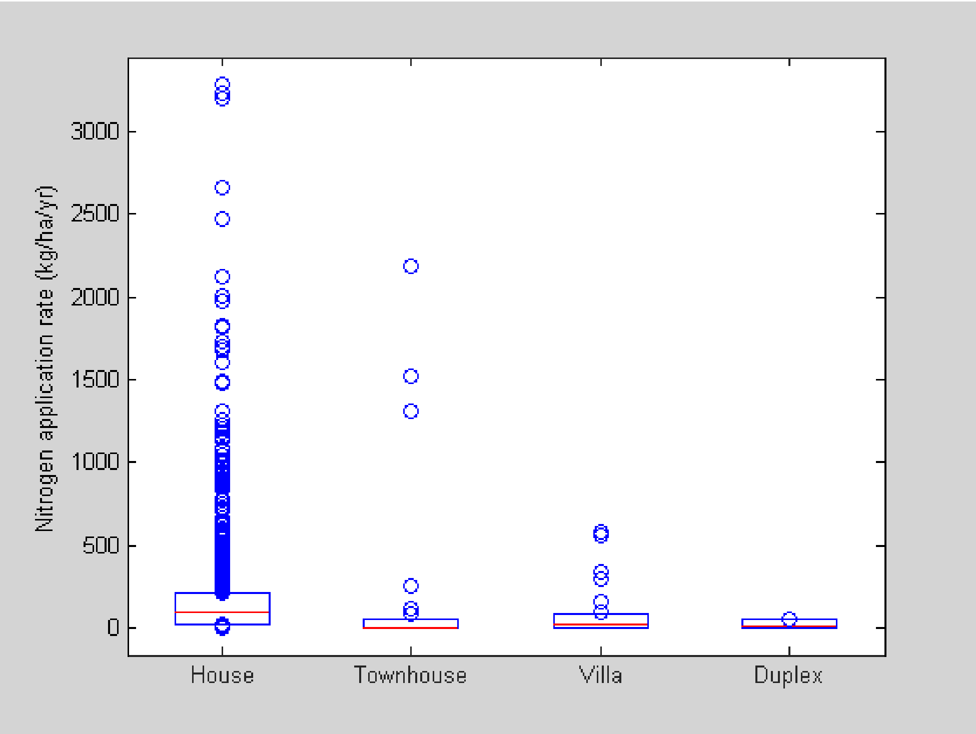
Note: there was a property which did not provide age, thus not used in age analyses

Age of residence also appeared to influence urban nitrogen and phosphorus application rates. Kruskal-Wallis one-way ANOVAs revealed significant differences in application rate depending on dwelling age: for nitrogen $p = 0.0011$ and for phosphorus $p = 0.004$. Respondents living in ‘new’ homes (1–2 years) applied significantly more nitrogen and phosphorus than those in ‘established’ and ‘old’ homes (six years and older). There was also a significant difference in phosphorus application between ‘new’ (1–2 years) and ‘recent’ (3–5 years) homes. ‘Brand new’ homes (less than 12 months old) weren’t found to be significantly different to any other of the age groupings.

4.3.3 Dwelling type

The plot of the nitrogen input rates against dwelling type is shown in Figure 4.11 and the medians and 25th and 75th percentiles are listed in Table 4.12. The corresponding plot and statistics for phosphorus are in Figure 4.12 and Table 4.13 respectively.

Kruskal-Wallis ANOVAs revealed significant differences in application rate depending on the type of dwelling: $p < 0.0001$ for both nitrogen and phosphorus. People living in 'houses' applied significantly more nitrogen to their land than did those in 'townhouses', 'villas' and 'duplexes' as a whole. Respondents living in 'houses' also applied significantly more phosphorus than those in 'townhouses', and while they applied more than those in 'villas' and 'duplexes', the differences weren't significant. There were no statistically significant differences between nutrient inputs for 'townhouses', 'villas' and 'duplexes'.



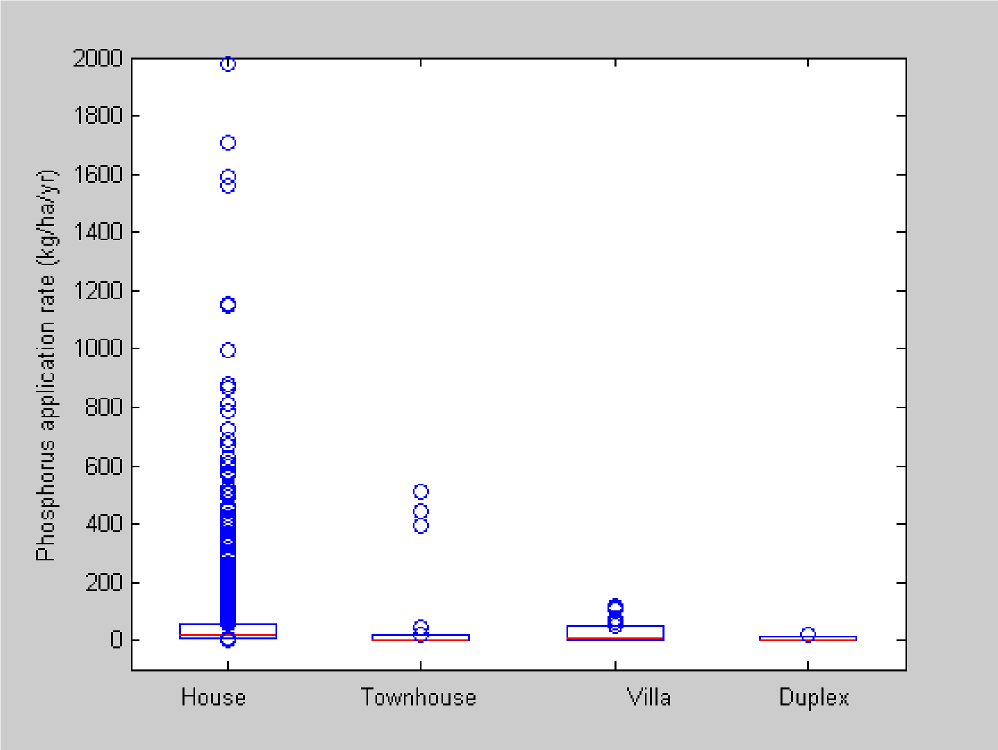
Outlier removed for visual clarity; database ID 155 was a new, owner-occupied house on a small block in Beechboro, total nitrogen 10 680 kg/ha/year.

Figure 4.11 Nitrogen input rate (fertilisers and pet waste) by dwelling type

Table 4.12 Nitrogen medians and 25th and 75th percentiles by dwelling type

	Nitrogen input rate (kg/ha/year)			
Type	25th percentile	Median	75th percentile	Sample size
House	22.9	89.4	213	881
Villa	0	17.8	85.7	25
Duplex	0	11	44.9	6**
Townhouse	0	0	38.1	24
All lots	19.5	84.1	207	936

***A sample size of 6 is not a large enough sample on which to base conclusions about the population of those who live in duplexes.*



Outlier removed for visual clarity; database ID 155 was a new, owner-occupied house on a small block in Beechboro, total phosphorus 3737 kg/ha/year.

Figure 4.12 Phosphorus input rate (fertilisers and pet waste) by dwelling type

Table 4.13 Phosphorus medians and 25th and 75th percentiles by dwelling type

	Phosphorus rate input (kg/ha/yr)			
	25th percentile	Median	75th percentile	Sample Size
House	6	21.1	59.3	881
Villa	0	5.93	49.1	25
Duplex	0	2.75	11.3	6**
Townhouse	0	0	18	24
All lots	5.1	19.7	57.7	936

***A sample size of 6 is not a large enough sample on which to base conclusions about the population of those who live in duplexes.*

4.3.4 Suburb

Differences between suburbs are expected because dwellings with specific characteristics were targeted in each suburb. However, differences may exist due to other factors (e.g. socio-economic), which have not been tested in this study. Kruskal-Wallis one-way ANOVAs showed significant differences between suburbs: for both nitrogen and phosphorus $p < 0.0001$. The suburb with the lowest nitrogen and phosphorus inputs was Victoria Park. (Note that 'old' and 'established' villas and units on small blocks were targeted in Victoria Park). On the other hand, Beechboro, Madora Bay, West Busselton, Tapping, Abbey Waters and Baldivis had the largest median values, with more than 120 kg/ha/year for nitrogen and 27 kg/ha/year for phosphorus.

Not all differences between suburbs were significant and it would be tedious to explain all the differences (i.e. which suburbs had significantly higher or lower nutrient input rates) due to the number of suburbs.

The nitrogen input rate medians and 25th and 75th percentiles for each suburb are listed in Table 4.14 and plotted for some suburbs in Figure 4.13. The phosphorus statistics and plot are in Table 4.15 and Figure 4.14 respectively.

Table 4.14 Nitrogen medians and 25th and 75th percentiles by suburb

	Nitrogen input rate (kg/ha/year)			
Location (suburb)	25th percentile	Median	75th percentile	Sample size
Victoria Park	0	3.2	49.0	34
Cannington	1.8	15.6	80.3	18
Subiaco	10.2	45.6	112	33
Halls Head	18.8	57.6	119	81
Mt Hawthorn	21.2	59.1	163	77
Broadwater	39.1	66.7	103	9
Busselton	13.9	71.6	163	67
Floreat	12.4	74.2	189	115
Carramar	47.6	79.0	161	27
Leeming	24.5	80.1	190	98
Meadow Springs	21.2	81.5	193	49
Yangebup	22.7	87.4	228	33
Henley Brook	24.0	98.2	267	44
Stratton	0	98.6	210	35
Beechboro	33.6	124	404	62
Madora Bay	64.5	131	190	11
West Busselton	56.0	137	158	25
Tapping	65.9	148	249	31
Abbey Waters	8.5	160	197	9
Baldivis	56.5	181	345	78

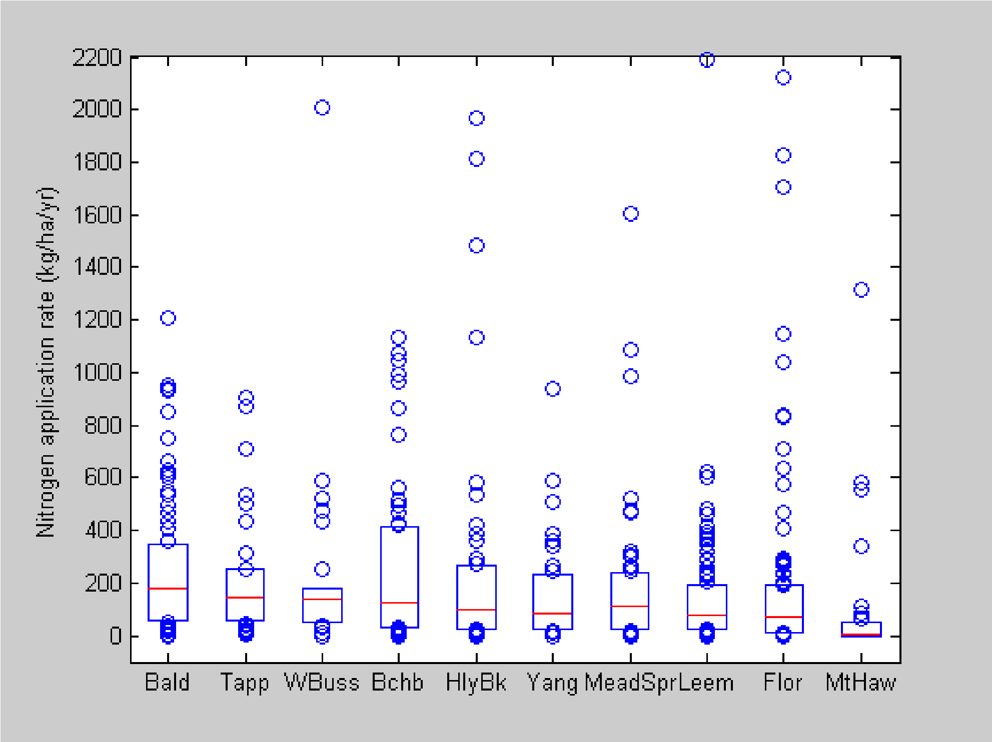


Figure 4.13 Nitrogen input rates (fertilisers and pet waste) by suburb

Table 4.15 Phosphorus medians and 25th and 75th percentiles by suburb

	Phosphorus input rate (kg/ha/yr)			
Location (suburb)	25th percentile	Median	75th percentile	Sample size
Victoria Park	0	0.8	9.3	34
Cannington	0	3.9	20.1	18
Halls Head	4.0	11.5	32.6	81
Subiaco	1.3	14.2	35.1	33
Broadwater	6.5	15.8	34.2	9
Floreat	3.4	16.1	58.4	115
Mt Hawthorn	6.5	16.9	39.4	77
Carramar	10.5	18.3	39.9	27
Busselton	4.6	18.9	53.9	67
Leeming	7.1	19.3	54.9	98
Yangebup	7.9	19.8	58.5	33
Meadow Springs	7.0	20.1	55.9	49
Henley Brook	4.0	23.1	62.0	44
Stratton	0	24.7	56.1	35
Tapping	13.7	26.0	70.1	31
Madora Bay	13.4	27.9	61.6	11
Beechboro	7.0	30.0	81.6	62
Baldivis	14.7	33.0	86.3	78
Abbey Waters	2.0	38.2	67.4	9
West Busselton	16.4	38.4	59.4	25

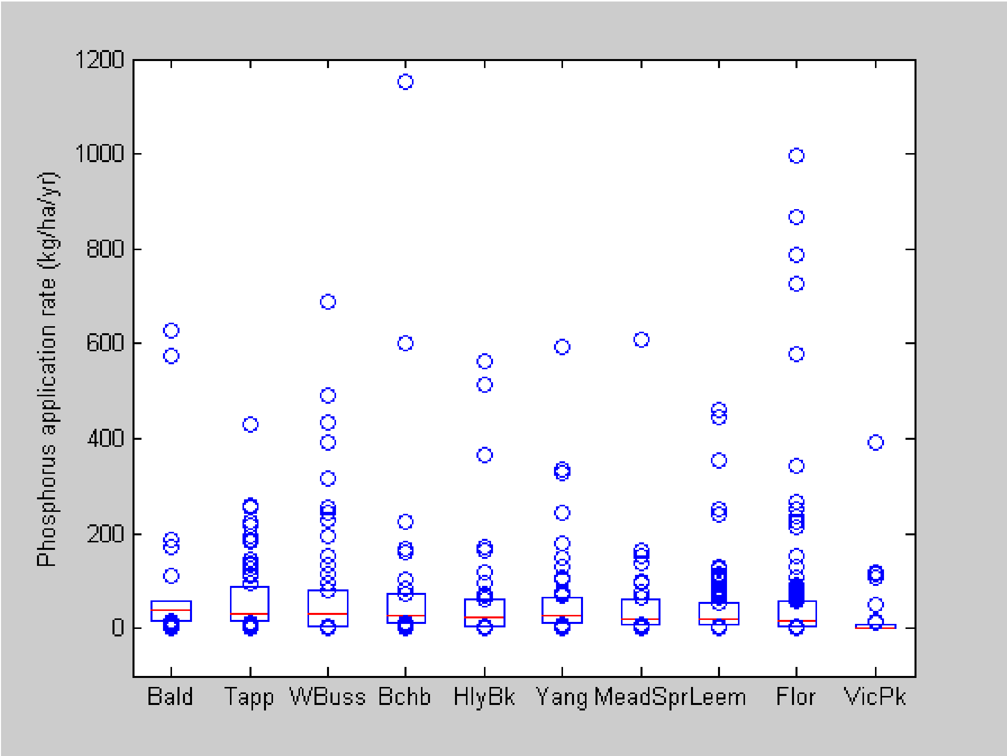


Figure 4.14 Phosphorus input rates (fertilisers and pet waste) by suburb

Because certain dwellings were targeted in each suburb, the input rates relate to the specified dwelling type in the suburb, and not to the suburb as a whole. For example, the low nutrient input rates for Victoria Park and Cannington are unlikely to represent the whole suburb because small lot sizes were surveyed – which does not reflect the 'median' or 'average' lot size in these suburbs. In Victoria Park, villas and units on small blocks were targeted, representing a small subset of the residential dwellings in this suburb.

Baldivis had the highest median nitrogen input rate of 181 kg/ha/year (compared with the median of all data of 84.1 kg/ha/year) and West Busselton had the highest phosphorus median input rate of 38 kg/ha/year (compared with the median of all data of 19.7 kg/ha/year).

It is also interesting to note that the suburbs that shared boundaries and were grouped together for the distribution of the surveys – Abbey Waters and Broadwater, Meadow Springs and Madora Bay, and Tapping and Carramar (see Appendix A) – had quite different median nutrient input rates, as shown in Table 4.16.

Table 4.16 Comparison between median nutrient input rates for Abbey Waters and Broadwater, Meadow Springs and Madora Bay, and Tapping and Carramar

Suburb	Median nitrogen (kg/ha/yr)	Median phosphorus (kg/ha/yr)
Abbey Waters	160	38.2
Broadwater	66.7	15.8
Meadow Springs	81.5	20.1
Madora Bay	131	27.9
Tapping	148	26.0
Carramar	79.0	18.3

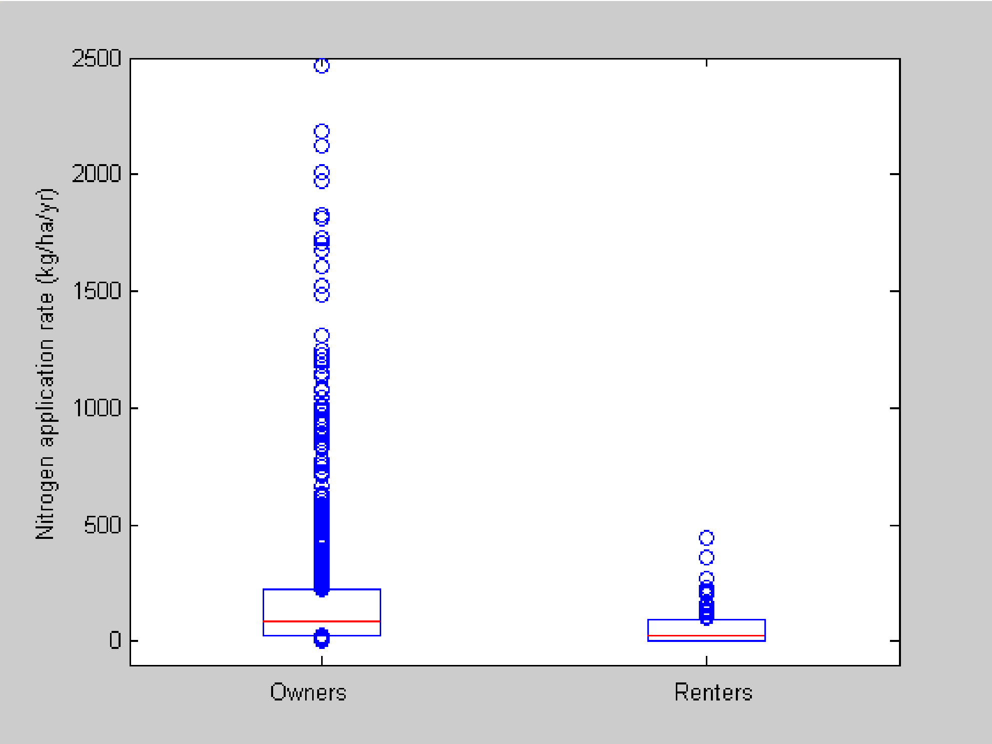
Despite the many apparent differences between fertilisation habits and input rates for the various suburbs surveyed, no differences were established between the Perth metropolitan area and the regional centres of Mandurah and Busselton.

4.3.5 Owners and renters

Occupants who owned the dwelling applied significantly more nitrogen and phosphorus to their land than did renters, $p < 0.0001$ for both nitrogen and phosphorus. The medians and the 25th and 75th percentiles are shown in Table 4.17 and Table 4.18 for nitrogen and phosphorus respectively, and the data are plotted in Figure 4.15 and Figure 4.16.

Table 4.17 Nitrogen input rate medians and 25th and 75th percentiles by owner/renter group

	Nitrogen input rate (kg/ha/year)			
Occupant	25th percentile	Median	75th percentile	Sample size
Owner	23.0	90.0	222	863
Renter	0	23.0	97.0	73

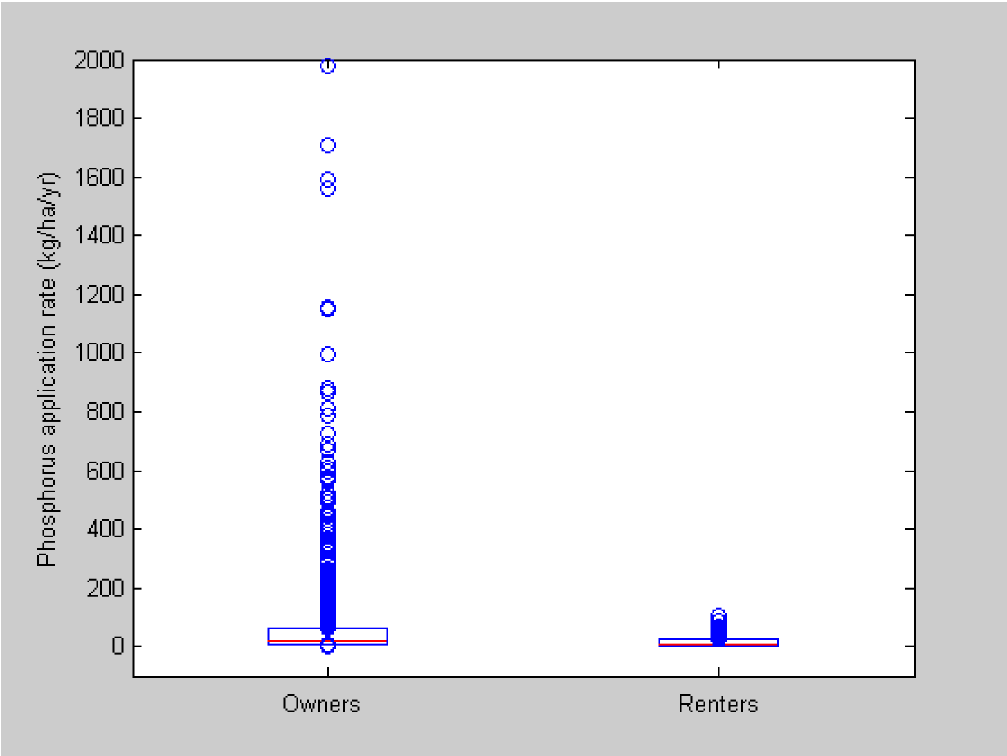


Outlier removed for visual clarity; database ID 155 was a new, owner-occupied house on a small block in Beechboro, total nitrogen 10 680 kg/ha/year.

Figure 4.15 Nitrogen input rates (fertilisers and pet waste) by owner and renter

Table 4.18 Phosphorus input rate medians and 25th and 75th percentiles by owner/renter group

	Phosphorus input rate (kg/ha/yr)			
Occupant	25th percentile	Median	75th percentile	Sample size
Owner	6.0	21.0	61.0	863
Renter	0	6.0	25.0	73



Outlier removed for visual clarity; database ID 155 was a new, owner-occupied house on a small block in Beechboro, total phosphorus 3737 kg/ha/year.

Figure 4.16 Phosphorus input rates (fertilisers and pet waste) by owner and renter

It may be thought that this result is partly because most renters never fertilise, however this is not true. Of the 110 renters in the dataset, only 20 of them never used fertiliser (18%). It was interesting to note that of those who used fertiliser, owners applied significantly more fertiliser per hectare than renters. To test this, a subset of respondents who used fertiliser was analysed using main effects ANOVA. The results showed that owners who fertilised applied more nutrients (both nitrogen and phosphorus) to the soil than did renters who fertilised, $p = 0.0$ in both cases. (The parametric ANOVA test was appropriate because the zero values were not included and the log of the data had a normal distribution.)

5 Discussion

5.1 Comparison with previous studies

Previous studies of nutrient inputs to urban residential areas in Western Australia were done by CSIRO in the 1990s (Gerritse et al. 1992; Gerritse et al. 1990) and Jim Davies and Associates (JDA) in the 2000s (JDA 2002; JDA 2004). These are discussed separately below.

5.1.1 CSIRO

Gerritse et al. (1992) investigated nutrient inputs in the residential areas of Gooseberry Hill, Mundaring and Susannah Brook, which had median lot sizes of 1300 m^2, 1900 m^2 and 2020 m^2 respectively. Because these lot sizes are much larger than those of this *urban nutrient survey* (median lot size is 680 m^2), a comparison is not appropriate. For residences in Gooseberry Hill, which had a median lot size of 1300 m^2 (average of 1500 m^2), the average nitrogen and phosphorus inputs from garden products were estimated to be 16.6 kg/ha/year and 4.3 kg/ha/year respectively. The total inputs were higher: 155 kg/ha/year for nitrogen and 33 kg/ha/year for phosphorus, due to inputs from household products, pets and septic tanks.

In their 1990 paper Gerritse et al. discuss the results of a survey done in Ballajura, which has an average lot size of 700 m^2 and connection to reticulated deep-sewerage. Of the 120 questionnaires delivered, 60 were completed: 31 from an established housing area and 29 from a new housing area (50% return rate!). The questionnaire requested information on garden products (fertilisers, herbicides, fungicides, pesticides, soil additives and animal products); dwelling, garden and lawn areas; bore water use; commercial spraying; and animals owned.

From the survey Gerritse et al. deduced nutrient input rates for sewered residential areas with housing density of 10/ha to be 80 kg/ha/year for nitrogen and 40 kg/ha/year for phosphorus. Contribution from pets appeared not to be included in these estimations. Inputs to urban areas such as watered council parks and gardens were estimated to be 150 to 200 kg/ha/year of nitrogen and 30 to 40 kg/ha/year of phosphorus.

The estimated input rates from Gerritse et al. (1990) are much less than the average fertiliser input rates determined in the *urban nutrient survey* for medium-sized lots (601–730 m^2), which were approximately 169 kg/ha/year for nitrogen and 58 kg/ha/year for phosphorus. Note that seven properties had nitrogen fertilisation rates of more than 1 tonne/ha/year, which were not included in these averages, so they differ from the values given in Table 4.5.

Gerritse et al. (1990) did not estimate nutrient inputs from pets, but reported 33 cats and 24 dogs in the 60 dwellings – which gives average input rates for pets of 2.7 kg/house/year of nitrogen and 0.67 kg/house/year of phosphorus (using data from Table 3.2). In the *urban nutrient survey*, 547 dogs and 364 cats were reported in the 1206 properties surveyed. Using the estimates of animal nutrient input from Table 3.2, this gives estimated nitrogen input of 2.8 kg/house/year and phosphorus input of 0.69 kg/house/year, which are similar to the estimations of Gerritse et al. even though the ratio of dogs to cats is different.

5.1.2 Jim Davies and Associates Pty Ltd (JDA)

More recently, JDA surveyed five residential developments in the Perth metropolitan area to determine nutrient inputs (JDA 2002). Two methods were used: aerial photography analyses and a questionnaire. The aerial photography method determined input rates by estimating the area of lawn and garden and assuming rates of fertiliser application as recommended by fertiliser manufacturers (did not include pet waste).

Their survey of 500 properties (100 in each development) produced 94 completed questionnaires, 10 to 26 from each suburb. The questionnaire method determined nutrient input per lot from fertiliser, pet waste and car wash detergent. The nutrient input rates reported from the analysis of the questionnaires are average values.

It is interesting to note that input rates from the aerial photography method are lower than those estimated from the survey responses (even allowing for pet inputs), especially for phosphorus. This is shown in Table 5.1 and Table 5.2. This indicates that house owners apply more fertiliser than their gardens and lawns need, and the excess has the potential to leach to waterways.

JDA estimated average input rates at the cadastral scale, which were referred to as input (mass)/net ha/year. They then made assumptions about the percentage areas and fertilisation rates of public open space and roads, to deduce suburb-scale nutrient input rates (kg/gross ha/year). Because the *urban nutrient survey* has derived values of nutrient input for cadastral parcels, the comparison presented here is with the inputs per net ha from JDA's report. The input rates at the cadastral scale are greater than the input rates at the suburb scale because 18% of the suburb is estimated to have no nutrient input (roads) and the fertilisation rates of public open space (estimated at 22% of the area) are less than the fertilisation rates of house blocks.

JDA estimated nutrient inputs for the following:

- Subi Centro, average block size 293 m^2

and four suburbs zoned R17.5[1]

- The Avenues, average block size 702 m^2
- Sanctuary Waters, average block size 680 m^2
- Brookland Greens, average block size 671 m^2
- Huntingdale, average block size 700 m^2.

The *urban nutrient survey* also surveyed Subiaco so that this suburb's surveys can be compared. Leeming and Yangebup from the *urban nutrient survey* are considered to be the suburbs most similar to the four R17.5 suburbs that JDA surveyed.

Table 5.1 contains the average nitrogen input rates determined by JDA and the *urban nutrient survey*, and the median inputs from the *urban nutrient survey*. Table 5.2 contains the phosphorus input rates.

[1] The metropolitan R-code refers to the maximum number of lots allowable in 1 ha. Thus R17.5 means that minimum lot size is 571 m^2.

Table 5.1 Nitrogen input rates (cadastral scale) from JDA (aerial photo analysis and survey) and the urban nutrient survey

JDA					*Urban nutrient survey*				
Suburb	# surveys	Average lot area (m^2)	Average nitrogen input rate (kg/ha/year)			# surveys	Average lot area (m^2)	Average nitrogen input rate (kg/ha/year)	Median nitrogen input rate (kg/ha/year)
			Aerial photos	Survey					
Subi Centro	10–26	293	34	61	Subiaco	49	297	270	46
The Avenues	10–26	702	138	166	Leeming	115	744	151	80
Sanctuary Waters	10–26	680	133	136	Yangebup	41	692	163	87
Brookland Greens	10–26	671	121	145					
Huntingdale	10–26	700	-	165					

Table 5.2 Phosphorus input rates (cadastral scale) from JDA (aerial photograph analysis and survey) and the urban nutrient survey

JDA					*Urban nutrient survey*				
Suburb	# surveys	Average lot area (m^2)	Average phosphorus input rate (kg/ha/year)			# surveys	Average lot area (m^2)	Average phosphorus input rate (kg/ha/year)	Median phosphorus input rate (kg/ha/year)
			Aerial photos	Survey					
Subi Centro	10–26	293	7.5	25	Subiaco	49	297	91	14
The Avenues	10–26	702	29	45	Leeming	115	744	47	19
Sanctuary Waters	10–26	680	29	40	Yangebup	41	692	56	20
Brookland Greens	10–26	671	29	45					
Huntingdale	10–26	700	-	46					

For Subiaco, the average nitrogen and phosphorus input rates from the *urban nutrient survey* are much greater than those reported by JDA. The *urban nutrient survey* targeted townhouses in Subiaco (no flats, units or businesses – see Appendix A), whereas JDA targeted Subi Centro, which means different types of dwellings were most likely included in their survey. Examination of the *urban nutrient survey* data revealed three dwellings in Subiaco that applied more than 1.5 tonnes/ha/year of nitrogen to their properties. If these are removed from the analyses, the average and median nitrogen input rates become 83 and 28 kg/ha/year respectively, and the average and median phosphorus input rates become 34 and 12 kg/ha/year respectively, which agree fairly well with the JDA survey, considering the different types of dwellings targeted.

The suburbs zoned R17.5 in JDA's survey (The Avenues, Sanctuary Waters, Brookland Greens and Huntingdale) have average nitrogen rates ranging from 136 to 166 kg/ha/year, which agree with the values for Leeming and Yangebup of 151 and 163 kg/ha/year respectively. The average phosphorus input rate for Leeming of 47 kg/ha/year is similar to the rates for the R17.5 suburbs in JDA's survey (40–46 kg/ha/year). The rate for Yangebup is slightly greater at 56 kg/ha/year.

JDA determined that about 10% of both nitrogen and phosphorus inputs comes from pet waste compared with the values of 9% and 7% for nitrogen and phosphorus deduced from the *urban nutrient survey*.

5.2 Nutrient input rates for catchment models

5.2.1 Median or average

DAFWA and the Department of Water have surveyed landholders in rural and urban areas to determine nutrient inputs to agricultural and urban land uses. The nutrient input-rate data derived from both the rural and urban surveys are skewed, thus medians are used as the measure of central tendency. For the *urban nutrient survey*, statistical analyses were undertaken using Kruskal-Wallis non-parametric tests.

Median values of nutrient inputs at cadastral scale are used as input for catchment nutrient export models such as SQUARE, WaterCAST and SSPND. In this study median values are reported, except for Table 4.4 and Table 4.5 (which list average pet and total nutrient input rates respectively) and the previous section's discussions.

Previous urban nutrient surveys undertaken by Gerritse et al. (1990) and JDA (2002) reported average values of nutrient input rates. However they had only 60 and 94 surveys to analyse respectively, compared with the *urban nutrient survey* where 936 of the 1206 returned surveys were used for statistical analyses. Gerritse et al. (1992) analysed 147 surveys from three locations and reported both medians and averages. Their data did not appear as skewed as that from the *urban nutrient survey*. The properties surveyed were in the residential areas of Gooseberry Hill, Mundaring and Susannah Brook, and had relatively large blocks sizes (median values of 1300 m^2, 1900 m^2 and 2020 m^2 respectively). Comparison with previous surveys was discussed in Section 5.1.

5.2.2 Input rates

Five independent variables were used in the analyses of nutrient input rates to urban residential lots – lot size, dwelling age, dwelling type, location and occupancy (owner/renter). There were statistical differences in nitrogen and phosphorus input rates with respect to each of the independent variables. Yet only lot size and dwelling age will be used to infer nutrient input rates for catchment models.

There are clear differences between nutrient input rates for different dwelling types. 'Houses' have significantly greater nutrient input rates than the other dwelling types ('townhouse', 'villa' and 'duplex'). The other dwelling types have nutrient input rates that are not statistically different. Because lot size is strongly correlated to whether a dwelling is a freestanding 'house', or a 'townhouse', 'villa', or 'duplex', it is assumed that the variability due to dwelling type is adequately represented by the variability due to lot size.

As the *urban nutrient survey* was not truly randomised and particular dwelling characteristics were targeted in each location (suburb), the differences deduced between suburbs do not reflect the whole suburb but only the dwelling types targeted in that suburb. Thus the location (suburb) input rates listed in Table 4.14 and Table 4.15 cannot be used for all dwellings in the suburb, but only those similar to the targeted dwellings in the suburb.

There are clear differences between nutrient input rates of renters and owners. Although the Australian Bureau of Statistics has information on home occupancy (owner/renter) for broad statistical regions (ABS 2005), it would be difficult to determine which cadastral parcels are occupied by owners or renters, or on a subcatchment basis the relative proportions of owners and renters. This will not be taken into account when determining input rates for catchment models, but may be considered for investigation in the future.

Lot size and dwelling age greatly influence nutrient input rates and will be used to determine the input rates for catchment modelling, when adequate data on lot size and age of dwelling are available.

Because there are significant differences between nitrogen and phosphorus input rates for all lot sizes, apart from 'small' which is not significantly different to either 'large' or 'medium', it was decided to keep the four lot sizes separate. When data on lot size are available, the nutrient input rates from fertilisers and pet waste in terms of lot size (listed in Table 5.3) will be used for catchment modelling. When data on lot size are not available, the input rates will be the median values of the whole dataset; that is, 84.1 kg/ha/year for nitrogen and 19.7 kg/ha/year for phosphorus.

Table 5.3 Nutrient input rates from fertilisers and pet waste for houses of various lot sizes

Lot size	Area (m^2)	Nitrogen (kg/ha/year)	Phosphorus (kg/ha/year)
Very small	≤ 400	23.4	6.9
Small	401–600	91.2	22.8
Medium	601–730	101	26.4
Large	> 730	74.2	18.0
All lots		84.1	19.7

From the results discussed in Section 4.3.2, 'new' homes (1–2 years) applied significantly more phosphorus than 'recent', 'established' and 'old' homes (i.e. all dwellings > 2 years). 'New' homes (1–2 years) also applied significantly more nitrogen than 'established' and 'old' homes (all dwellings ≥ 6 years). 'Brand new' homes (< 12 months old) were not found to be significantly different to any other of the age groupings.

There were only 23 'brand new' homes (< 12 months old) in the dataset. If the new occupant has begun work on their garden, their fertilisation rate will be similar to that of 'new' homes (1–2 years); if they have not begun work, their fertilisation rate will be zero. Thus, for catchment modelling inputs, 'brand new' homes (< 12 months old) will be grouped with 'new' homes (1–2 years).

Consequently, input rates for catchment models will be modified to apply greater nitrogen and phosphorus to homes 0–2 years old, compared with those older than 2 years, when the age of dwellings is known. The nutrient input rates from fertilisers and pet waste in terms of lot size and dwelling age are listed in Table 5.4. If the age of the dwelling is known, but not the block size, then the rates given for 'all lots' in Table 5.4 will be used.

Table 5.4 Nutrient input rates from fertilisers and pet waste for houses of various lot size and dwelling age

		Nitrogen (kg/ha/year)		Phosphorus (kg/ha/year)	
Lot size	Area (m^2)	≤ 2 years old	> 2 years old	≤ 2 years old	> 2 years old
Very small	≤ 400	68.6	23.4	19.4	6.9
Small	401–600	115	87.6	33.2	20.3
Medium	601–730	177	92.9	43.7	24.7
Large	> 730	119	74.0	30.4	17.0
All lots		147	78.2	38.6	18.6

5.3 Comparison with rural land-use input rates

The nutrient input rates derived from the rural and urban nutrient surveys will be used to determine the relative impacts of different land uses. Population is increasing in Perth and many regional towns on the Swan Coastal Plain; in some areas urban development is replacing rural land uses. If the urban land use has greater nutrient inputs than the existing land uses, then the water quality of the adjacent streams and estuaries is likely to worsen.

Table 5.5 contains a list of rural and urban residential nutrient input rates. These data are also displayed in Figure 5.1 and Figure 5.2. Note that in Figure 5.1, the nitrogen inputs from piggeries and turf farms of 630 kg/ha/year and 433 kg/ha/year (respectively) exceed the y-axis scale. Similarly in Figure 5.2, the phosphorus input rates for piggeries and annual horticulture of 145 kg/ha/year and 127 kg/ha/year (respectively) exceed the y-axis scale.

Table 5.5 Nitrogen and phosphorus input rates for rural† and urban†† land uses

Land use	Nitrogen (kg/ha/year)	Phosphorus (kg/ha/year)
Piggery	629.3	144.7
Turf farm	432.8	14.5
Dairies	145.1	25.5
Annual horticulture (vegetables)	142.6	126.9
Urban residential (601–730 m^2)	100.6	26.4
Urban residential (401–600 m^2)	91.2	22.8
Beef grazing	86.4	12.7
Mixed grazing	79.5	9.9
Urban residential (> 730 m^2)	74.2	18.0
Horses	70.1	13.2
Lifestyle block	49.2	3.4
Cropping	46.7	8.4
Sheep	34.7	2.5
Perennial horticulture (orchids)	27.2	12.3
Viticulture	23.5	25.4
Urban residential (< 400 m^2)	23.4	6.9
Tree plantation	12.6	8.2

† Rural values determined from DAFWA farm-gate nutrient budgets undertaken in the CCI project (Ovens et al. 2008; Weaver et al. 2008)

†† Urban input rates are those for different lot sizes; age of dwelling not considered.

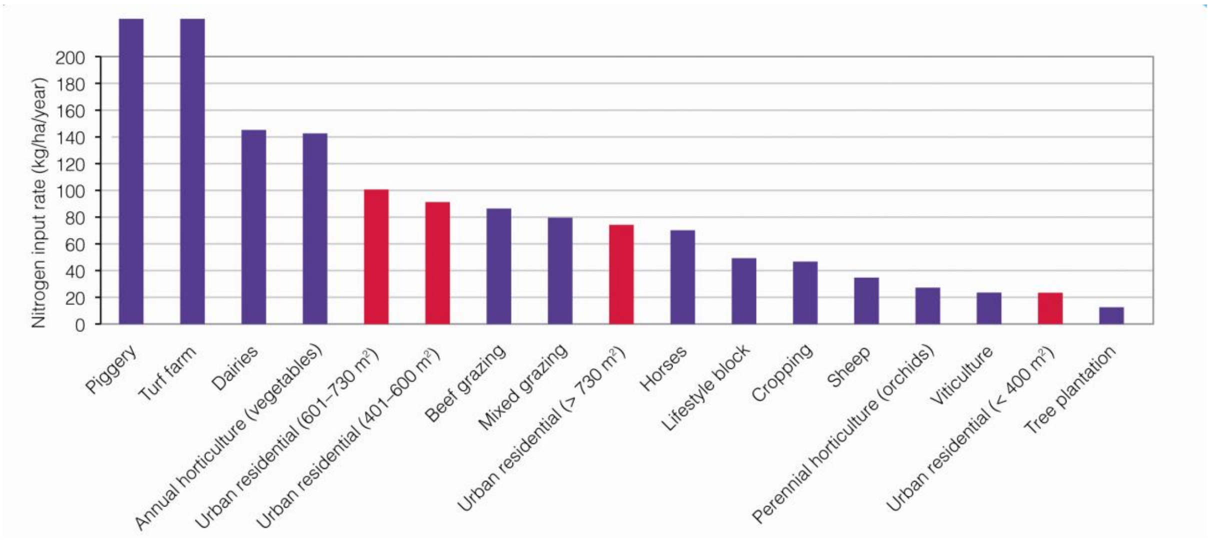


Figure 5.1 Total nitrogen input rates for rural and urban residential land uses ('piggery' inputs of 630 kg/ha/year and 'turf farm' of 433 kg/ha/year not fully displayed)

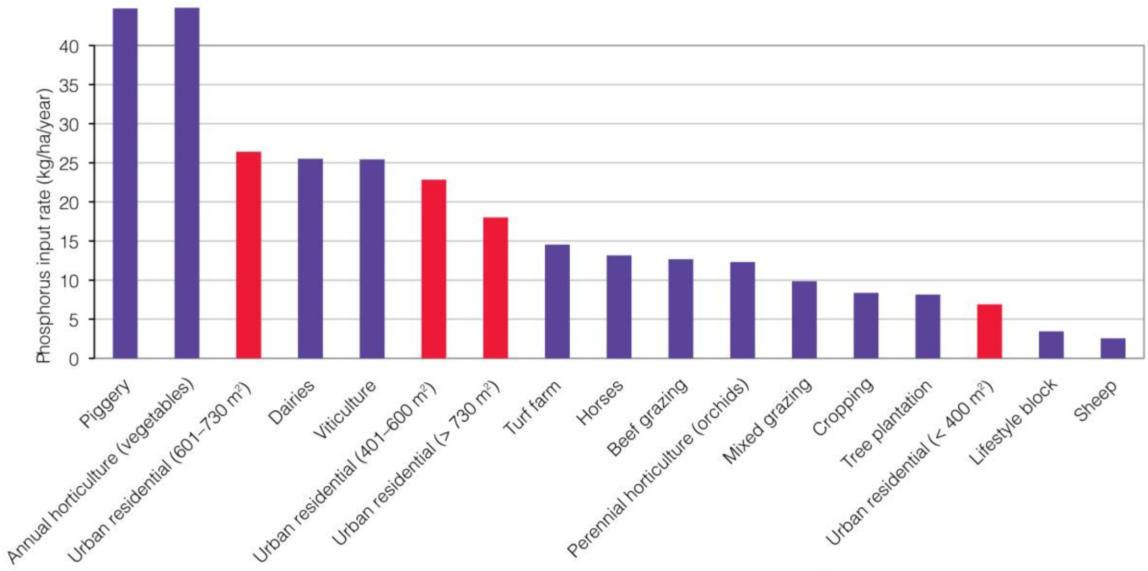


Figure 5.2 Total phosphorus input rates for rural and urban residential land uses ('piggery' inputs of 145 kg/ha/year and 'annual horticulture (vegetables)' of 130 kg/ha/year not fully displayed)

Future medium-density urban residential development is expected to have block sizes of 450 to 600 m^2. Residential properties of this size have greater nutrient input rates than the rural land uses that are generally displaced, such as 'beef grazing', 'mixed grazing', 'horse' and 'lifestyle blocks'. If the fertilisation practices of householders are not modified, then it is expected that urban development will further degrade adjacent rivers and estuaries.

The adoption of appropriate urban designs that minimise nutrient impacts on the Swan Coastal Plain's fragile ecology and promote rehabilitation of the rivers and estuaries is a challenge slowly being recognised by planning and environmental agencies. Options to limit nutrient inputs include higher density housing (< 400 m^2) with public open space managed appropriately, or the introduction of regulatory controls over fertilisation application and/or types of plants used in gardens. For example, Kelsey et al. (2009) estimates the implementation of the *Fertiliser action plan* and urban fertilisation reductions (of 50%) in the Swan-Canning coastal catchments have the potential to reduce nutrient inputs to the Swan and Canning rivers and estuaries by about 25%.

5.4 Recommendations for future surveys

5.4.1 Survey design

The *urban nutrient survey* was not truly random, because the aim was to determine the input rates for dwellings with certain characteristics. Surveyed locations and dwellings were selected based on their attributes. Thus, the differences deduced between suburbs are not reflective of the whole suburb, but only of the dwelling types targeted in that suburb; thus differences due to location cannot be inferred from this survey. For instance West Busselton appears to have large input rates – 137 kg/ha/year for nitrogen (about 1.5 times the median of all data) and 38.4 kg/ha/year for phosphorus (about double the median of all data). However the target dwellings in West Busselton were 'established homes on medium and large blocks/no subdivided blocks or duplexes' and it cannot be assumed that these input rates represent the medians of the all lots in the suburb.

It is recommended that future surveys are truly random so that differences between locations can be adequately quantified. It would also be interesting to survey in such a way that socio-economic variables could be investigated. This would be difficult as respondents would be required to give personal information, which is most likely inappropriate for this sort of survey.

The possible non-response bias should also be considered. As with any survey, there is the possibility of bias in favour of those who responded. For example, keen gardeners may be more willing to complete a survey of this type and may also apply more fertiliser. On the other hand, people who apply no fertiliser to their garden may be proud of this, and more inclined to return the survey than the people who do apply fertiliser. In the *urban nutrient survey*, of the 936 surveys used in the statistical analyses, 99 (11%) had nitrogen and phosphorus input rates of zero; that is, the respondents did not have pets and did not fertilise their lots.

Ideally there should be some sort of follow-up data collection to identify the non-respondents. This was not done for this survey but should be considered if future surveys are undertaken.

5.4.2 Questionnaire design

The *urban nutrient survey* had a good design and structure (see Appendix B), and was, for the most part, straightforward to complete. Yet a few problems were encountered in interpreting the raw data, which are discussed below (suggestions for avoiding them in future are also given).

Instances of possible ambiguities can be found in both Question 1 on dwelling type and Question 19 on fertiliser use. As definitions of the semi-detached dwelling types: 'villa', 'townhouse' and 'duplex' were not included in the survey, classification of the semi-detached dwelling types relied on the respondent's judgement. This might have resulted in the unclear statistical differences in nutrient application that were found between the non-house types. It may be better to give respondents two options only: 'stand-alone house' or 'semi-detached dwelling'; or alternatively provide clear definitions of the dwelling types in future surveys.

In Question 19 on the application of fertilisers, respondents were asked to estimate the amount of fertiliser they used in sizes of small or large bags, sacks or trailers. However, in some cases the commercially-sold bags of fertiliser have 'in between' sizes, which the respondent could not select.

There was also some ambiguity between true zeros and missing values. It is important to be able to distinguish between a true answer of zero and a question that was simply skipped by the respondent. The former enters the analysis as a zero and the latter is most often removed from the analysis. For questions requiring counts or percentages, such as those on numbers of pets (Question 8) and percentage area of land use (Question 10), respondents could have been told to enter a zero in all boxes where they meant 'none', which would have helped identify the true zeros from the missing values.

There were some cases of illogical answers, the incidence of which can be reduced by the wording of the question. Answers to the two parts of Question 9 about pet-waste disposal on-property and off-property were sometimes mutually exclusive. For example, it was possible to have the combinations about pet-waste disposal: ‘all on-property’ and ‘all off-property’ or ‘all on-property’ and ‘most off-property’. It would have been better to combine these two parts into the one; for example, ‘do you dispose all pet waste on-property and none off-property?’ Or, ‘do you dispose of no pet waste on-property and all off-property?’ Or ‘do you dispose some pet waste on-property and some off-property?’ Lastly, ‘4’ was the code for ‘none’, but some people were confused by this and entered ‘0’ instead. It would have been better if ‘0’ had been the code for ‘none’.

6 Conclusions

The *urban nutrient survey* queried 7000 residents in 17 locations in Western Australia's Swan-Canning, Peel-Harvey and Geographe Bay catchments. The 1206 responses allowed estimations of nitrogen and phosphorus inputs from fertilisation and pet waste (cats and dogs) to residential urban areas.

The following observations were made:

- There was a wide range of nutrient inputs for dwellings with similar characteristics, with some people applying very large amounts of fertiliser (at greater rates than market gardens).
- Most nutrient inputs were from fertilisation of gardens. Breakdown of inputs (by weight):

	Nitrogen	Phosphorus
Garden	70%	81%
Lawn	21%	12%
Pets	9%	7%

- Most of the fertiliser is organic – such as manures, mulches and composts (64% of nitrogen and 75% of phosphorus fertilisation is organic).
- During the past 10 years there appears to have been an **increase** in the number of dwellings with **no** native plants in their gardens.

Statistical analyses on input rates; that is, the mass of nitrogen and phosphorus input per hectare per year for the lots surveyed, showed:

- The data were very skewed, with a small number of properties having very large nutrient input rates. Thus, median values were used as the measure of central tendency, and Kruskal-Wallis non-parametric tests were used to determine if there were statistically significant differences in the data.
- There were significant differences between nutrient input rates for properties with different characteristics; namely lot size, lot age, dwelling type and whether occupied by an owner or renter.
- Statistical differences were apparent between nutrient input rates of properties in different locations. However this was expected because dwellings with different characteristics were targeted in different locations. No differences were apparent between the Perth metropolitan area and the regional centres of Mandurah and Busselton.
- The **average** nutrient input rates deduced by the *urban nutrient survey* agree with those from JDA's survey of four R17.5 suburbs in the Southern River catchment (JDA 2002). Note that average input rates quoted in the previous studies by JDA and Gerritse et al. (1990, 1992) cannot be directly compared with the median values listed in most of this document.
- Nutrient inputs as pet waste are slightly less than those of JDA's survey, but agree with data from Gerritse et al. (1992).

- The average and median input rates (fertiliser and pets) for all the data were:

  Nitrogen (kg/ha/year):

Average	Median
208	84.1

  Phosphorus (kg/ha/year):

Average	Median
72.0	19.7

- For catchment modelling (SQUARE, WaterCAST and SSPND), the input rates in terms of lot size are given below:

Lot size	Area (m^2)	Nitrogen (kg/ha/year)	Phosphorus (kg/ha/year)
Very small	≤ 400	23.4	6.9
Small	401–600	91.2	22.8
Medium	601–730	101	26.4
Large	> 730	74.2	18.0
All lots		84.1	19.7

- If dwelling age is also known, the input rates in terms of lot size are:

		Nitrogen (kg/ha/year)		Phosphorus (kg/ha/year)	
Lot size	Area (m^2)	≤ 2 years old	> 2 years old	≤ 2 years old	> 2 years old
Very small	≤ 400	68.6	23.4	19.4	6.9
Small	401–600	115	87.6	33.2	20.3
Medium	601–730	177	92.9	43.7	24.7
Large	> 730	119	74.0	30.4	17.0
All lots		147	78.2	38.6	18.6

- Future medium-density urban residential development is expected to have block sizes of 450 to 600 m^2. Residential properties of this size have greater nutrient input rates than the rural land uses that are generally displaced, such as 'beef grazing', 'mixed grazing', 'horse' and 'lifestyle blocks'.

Appendices

Appendix A — Instructions to distributors of surveys

Abbey/Broadwater	Don't deliver to vacant/incomplete blocks.
Baldivis	Target new homes on medium blocks.
	No subdivided blocks or duplexes.
	No vacant/incomplete blocks.
Beechboro	*No specific instructions.*
Busselton	Target large blocks.
	No subdivided blocks, villas or duplexes.
Cannington	Target newly built homes on small blocks, and units.
	Only deliver to units, duplexes or subdivided blocks.
Floreat	Target old homes on large blocks.
	Only deliver to stand-alone houses, not duplexes or subdivided blocks.
Halls Head	Target canal homes.
	Deliver to all dwellings regardless of size or type.
Henley Brook	*No specific instructions.*
Leeming	Target established homes on medium and large blocks.
	No units, duplexes or subdivided blocks.
Meadow Springs/ Madora Bay	Target new homes on medium and large blocks.
	No units, duplexes or subdivided blocks.
Mt Hawthorn	Target old homes on small blocks.
	Deliver only to stand-alone houses, not duplexes or subdivided blocks.
Stratton	Target established homes on small blocks.
	No duplexes or subdivided blocks.
Subiaco	Target townhouses.
	No flats, units or businesses.
Tapping/Carramar	Target houses 3–5 years old on small and medium blocks.
Victoria Park	Target units and villas.
	No multi-level flats or villas.
West Busselton	Target established homes on medium and large blocks.
	No subdivided blocks or duplexes.
Yangebup	Target established homes on medium and large blocks.
	No subdivided blocks or duplexes.

Appendix B — A completed survey

Department of Water
Government of Western Australia

Department of Water
Gardening Practices Community Survey

Section 1: About your property

1. Which of the following best describes your home and block?

Traditional 'stand alone' house	Villa	Townhouse	Duplex
☑1	☐2	☐3	☐4

2. Where do you live? **Suburb** BEECHBORO **Postcode** 6063

3. How long ago was the main house or unit built?

Less than 12 months	1-2 years	3-5 years	6-10 years	11+ years	Don't know
☐1	☐2	☑3	☐4	☐5	☐9

4. To the nearest 50 m^2, what is the size of your block:
If you are unsure, please try to make an estimate – eg: a block that is 20m by 30m is 600m^2

550 m^2 ☐9 Don't know

5. Are you the owner of the property, or are you renting?

Owner	Renting
☑1	☐2

6. Does the property have a septic tank or is it on deep sewerage (mains)?

Septic	Deep sewerage (mains)	Don't know
☐1	☑2	☐9

7. How many people live on the property in the following age groups?
Please write a number in each box - If there are none in an age group then leave the box blank or write in a "0"

Under 3	4-17	18-39	40-64	65+
0	2	0	2	0

8. How many pets or other animals live on the property?
Please write a number in each box - If there are none of a particular animal, then leave the box blank or write in a "0

None	Dogs	Cats	Horses	Chooks	Others
☐1	2	1	0	0	0
Skip to Q10	*Continue*	*Continue*	*Continue*	*Continue*	*Continue*

9. How much pet waste is disposed of in the following ways:

	All	Most	Some	None
On the property	☐1	☐2	☐3	☐4
Off the property (eg: In rubbish bins)	☑1	☐2	☐3	☐4

Section 2: Gardens and Lawns

10. Thinking about your block as a whole, what proportion would you estimate was used for each of the following: *Please estimate percentages; percentages should add to 100%*

The main dwelling (including attached carports and garages)	63 %
Other roofed buildings (sheds, detached carports and garages etc)	2 %
Paved / concrete / gravel areas (driveways, paths, parking etc)	15 %
Lawn	10 %
Gardens	10 %
Other (such as pools, bare sand areas, areas that are not yet landscaped, etc) *please describe*	%
Total	**100%**

11. Different types of plants take up different amounts of nutrients from the soil and use different amounts of water.

Thinking about the garden areas of your block, what would you estimate is the balance of the following:

Percentages for each pair should add to 100% (for example: 70% + 30% = 100%; or 50% + 50% = 100%).

These three questions are separate of each other, and each part looks at the garden overall

Native plants	20 %	+	**Non-native plants**	80 %	= 100%
Perennials (live 2+ years) This includes most trees and shrubs	85 %	+	**Annuals (live only 1 year)** For example: bulbs and flowering plants that live for only 1 season or year	15 %	= 100%
Low water usage Includes most local natives. Exotic examples include freesias, lavender, hibiscus, bougainvilleas and oleanders	40 %	+	**High water usage** Azaleas, ferns, frangipanis, fuchsia, geraniums, hydrangeas, jacarandas and roses are some common examples	60 %	= 100%

lavender. agapanthus Daisy Society garlic Rosemary

Azaleas, Roses.

12. Who takes care of the garden and lawns? *Tick all that apply for each area*

	You / your household	Lawnmower man	Permanent gardener / caretaker
Lawn	☑1	☐2	☐3
Gardens	☑1	☐2	☐3

13. How are garden waste and lawn clippings disposed of? *Tick all that apply*

	Garden waste	Lawn clippings
Composted on the property	☐1	☐1
Weekly / fortnightly roadside collection (in wheelie bins)	☑2	☑2
Kerbside pickup by local council (every 3 – 6 months)	☑3	☐3
Removed immediately from the property (eg: by lawnmower man)	☐4	☐4
Other (please describe):	☐5	☐5
Don't know	☐9	☐9

Part 3: Watering and Fertilisers

14. Is there a rainwater tank on the property?

Yes	No
☐1	☑2

15. What water source(s) are used to water lawns and gardens on your property? *Tick all that apply*

Scheme or tap water	Bore water	Rainwater from a tank
☑1	☐2	☐3

16. How do you water your lawn and garden areas? *Tick all that apply*

	Permanent reticulation with a timer	Permanent sprinklers manually turned on and off	Moveable sprinklers	Hand watering
Lawn	☑1	☐2	☐3	☐4
Gardens	☑1	☐2	☐3	☐4

17. What is the approximate total watering time (both hand and / or sprinkler watering) for lawns and gardens in a typical week…

	… during summer		… during winter	
	Lawns	*Gardens*	*Lawns*	*Gardens*
No watering	☐1	☐1	☑1	☐1
Less than 5 minutes	☐2	☐2	☐2	☐2
5 – 10 minutes	☐3	☐3	☐3	☑3 Depends on rain etc.
10 – 20 minutes	☑4	☐4	☐4	☐4
20 – 30 minutes	☐5	☑5	☐5	☐5
30 – 40 minutes	☐6	☐6	☐6	☐6
40 – 50 minutes	☐7	☐7	☐7	☐7
50 – 60 minutes	☐8	☐8	☐8	☐8
More than 1 hour	☐9	☐9	☐9	☐9

There are two types of fertilisers commonly used on lawns and gardens in Perth. Each of these has a different combination of 'ingredients' that are released, so it is important for us to try to understand exactly which fertilisers are being used.

Commercial chemical fertilisers Some common examples are:

1. Cresco Garden
2. Cresco Lawn Fertiliser
3. Cresco Advantage
4. Cresco NPK Blue
5. Dynamic Lifter Lawn Food
6. Dynamic Lifter Plant Food
7. Baileys Brilliant
8. Baileys 3.1.1
9. Baileys 4.1.1
10. Scott's Lawn Builder
11. Osmocote
12. Miracle-Gro
13. Thrive
14. Yates Weed'n'Feed

Organic fertilisers and mulches Including:

15. Chicken manure
16. Sheep manure
17. Cow manure
18. Horse manure
19. Soils aint Soils: Landscape Mix
20. Soils aint Soils: Vegie and flower mix
21. Mulch
22. Soil Conditioner

18. Have any fertilisers or mulches (either the ones listed or any others not in the lists) been used on your gardens or lawns in the last 12 months?

Yes	No	Don't know
☑ 1	☐ 2	☐ 9
Continue to last question	*Thank you, you have now finished the survey*	

***Note**: If the person who makes most of the decisions about fertilising is not in your household, you may need to try to get their input into the last question.*
If this is not easily done, then please just answer to the best of your own knowledge.

19. When and how have these fertilisers been applied?
For each different type of fertiliser or mulch used in the last 12 months, please complete a line in the following table

What fertiliser has been used? Write in a number from the tables above or the name of a fertiliser not listed. If you don't know the name, just write 'Commercial' or 'Organic'	**When was this applied?** Tick all that apply				**What area(s) was it applied to?** Tick all that apply		**How many times has this been used in the last 12 months?** Write in the number of times used	**How much was used on average each time it was applied** Write in the number or fraction that best describes how much was used (eg: 1 large bag; ½ a trailer load)			
	Summer	Autumn	Winter	Spring	Lawn	Gardens		Small bags	Large bags	Sacks	Trailers
Example: #5	✓			✓	✓		2		1		
#7	✓	✓		✓	✓			1			
#6				✓		✓	1		½		
#16				✓		✓	1		15		
#17				✓		✓	1		10		
#21				✓		✓	1				6

Also Riversafe – Soil Wetter Granules.

Thank you for taking the time to complete this survey – Please remember now to return it to us in the reply paid envelope.

Appendix C — Fertilisers used by respondents

Table C.1 Type, bulk density and percentage composition of fertiliser used by respondents

Fertiliser ID	Description	Organic / Inorganic (O/I)	Bulk density (kg/m^3)	%Composition by weight	
				Nitrogen	Phosphorus
1	Cresco garden	I		12	3.4
2	Cresco lawn fertiliser - slow release	I		12.3	1.8
3	Cresco advantage	I		15.9	0
4	Cresco npk blue	I	1286	12	5.2
5	Dynamic lifter lawn food 6kg/100m2	I	588	3.2	2.6
6	Dynamic lifter plant food	I	588	3.2	2.6
7	Baileys brilliance blend	I		16	0
8	Baileys 3.1.1 blend	I		12	1.8
9	Baileys 4.1.1	I		18	0
10	Scott's lawn builder (regular 2.5 kg/25m2)	I	1143	21.6	1.1
11	Osmocote '3/4 months'	I		14	6.1
12	Miracle-gro all purpose plant food	I		15	13.1
13	Thrive granular all purpose plant food	I	947	27	5.5
14	Yates weed'n'feed granular (1kg/15m2	I	25	5	
15	Chicken manure	O	700	3	4
16	Sheep manure	O	700	3	1
17	Cow manure	O	700	2.5	0.4
18	Horse manure	O	700	2	0.5
19	Soils aint soils landscape mix	O		3	2
20	Soils aint soils vegie and flower mix	O		3	2
21	Mulch	O	600	1.4	0.42
22	Soil conditioner	O	700	2.7	0.97
23	Yates blood n bone	O		5	5
24	Munns blood n bone	O	1100	4.5	4.5
25	Richgro npk blue	I		11.8	6
30	Agras	I		17.5	7.6
31	All Purpose Fertiliser (miracle gro all purpose plant food)	I		15	13.1
32	Ammonium sulphate (21% ammonium as N)	I	250	21	0
33	Baileys lawn green	I		10	3.4
34	Baileys mulch	O		1.4	0.42
35	Baileys phosphate free (4.1.1)	I		18	0
36	Brunnings hibiscus food	I		3.2*	2.6
37	Brunnings feed and mulch	O		1.4*	0.42
38	Brunnings slow release fertiliser for roses	I	1000	16	3
39	Bunnings Lawn Fertiliser	I	250	9	4
40	Commercial (use Dynamic lifter lawn food)	I	588	3.2	2.6
41	Commercial fertiliser - liquid (Yates weed n feed liquid)	I		11.6	0.7
42	Commercial lawn fertiliser (use Hortico lawn food)	I	1200	10	3.5
43	Compost	O		4	1
44	Curley top palm trace elements (assume N&P to be zero)	I		0	0
45	David grays hi lawn (premium green lawn fertiliser)	I	200	10	1.5
46	David grays rose (same as brunnings roses)	I		16	3

** Estimated values*

Table C1 (cont.)

Fertiliser ID	Description	Organic / Inorganic (O/I)	Bulk density (kg/m^3)	%Composition by weight Nitrogen	Phosphorus
47	Epsom salts gardenias (sulphate of magnesium)	I		0	0
48	Gard4grow lawn (use baileys 3.1.1)	I		12	1.8
49	Gingin loam	n/a		0	0
50	Golf Course Munn's Green	I	1286	12	5
51	Hortico (lawn food)	I	1200	10	3.5
52	Hortico target green lawn food	I		10	1.5
53	Lawn winter green	I	250	20	0
54	Magnesium Sulphate	I		0	0
55	Maxicrop liquid 1L, 5L, 20L, 200L	I		29	7.5
56	Mitre 10 complete garden (same as miracle gro all purpose plant food)	I		15	13.1
57	Munns organic (garden booster)	O	900	2.5	3.5
58	Munns buffalo booster	I	1100	14	0.5
59	Oasis fertiliser (just use dynamic lifter plant food)	I	588	3.2	2.6
60	Organic (hortico-ingredients are 100% chicken manure)	O	700	3	4
61	Organic 2000	O		4	1
62	Osmocote slow release	I	1000	17	1.6
63	Osmocote slow release native granules (sercul)	I		17	1.6
64	Phosphate free lawn builder	I		18	0
65	Phosphorus free lawn fertiliser	I		18	0
66	Plant food commercial (hortico plant food)	I	350	4	4
67	Potting mix (Hortico)	O	900	3	3
68	Power Feed	I		0.016	0.0015
69	Richgro	I	250	10	1.25
70	Richgro extra green 50 g (1 handful) /m2	I	250	10	1.25
71	Richgro Organic	O		3	4
72	Richgro super green	I	250	10	1.25
73	River friendly lawn fertiliser	I		5	0
74	Rose fertiliser (thrive granular)	I	350	7.6	4
75	Rose food (thrive granular)	I	350	7.6	4
76	Seasol	O		0.22	0.58
77	Seaweed (same as seasol)	O		0.22	0.58
78	Seaweed spray (same as seasol)	O		0.22	0.58
79	Soil wetter (granules - hortico)	I		0	0
80	Soil conditioner	O	700	2.7	0.97
81	Spring burst	I		3	3
82	Target green (assumed kg sizes)	I		10	1.5
83	Top dress lawn sand	n/a		0	0
84	Waldecks all purpose (use miracle gro all purpose plant food)	I		15	13.1
85	Weed n feed (brunnings feed n weed granular)	I	857.3	5	0
86	Wettasoil	I		0	0
87	Winter green	I	250	20	0
88	Urea	I		46	0
90	Richgro rose fertiliser	I	250	20	20
89	Wintergreen Lawn-richgro	I	250	20	0
	Lawn clippings	O		4	0.4

Appendix D — Statistical analyses

Kruskal-Wallis ANOVA significance test

The Kruskal-Wallis non-parametric analysis (Kruskal & Wallis 1952) was chosen as the test most appropriate because of the non-normality of the data. The Kruskal-Wallis one-way analysis of variance significance test determines if there are statistical differences between the medians of the dependent variables, by ranking the values in terms of their magnitudes, and then testing for the difference between the means of the ranks. If the *p-value* is deemed significant then there is a difference that cannot be attributable to chance between at least two of the median values.

For each of the groups of independent variables: lot size, dwelling age, dwelling type, location and occupancy, the Kruskal-Wallis test determined there was a significant difference between at least two of the populations. The *p-value* was < 0.001 for all of the groups.

Matlab™ 'multcompare' function

The 'multcompare' function in Matlab™ was used to test each of the pairs of means to determine which were significantly different. Because there were many independent variables and thus many pairings of independent variables, the significant differences were mentioned in the text, but the statistical analyses were not included.

'Multcompare' returns a matrix of pairwise comparison results and an interactive graphical representation of the test. When there are many pairs to compare, the use of t-tests is inappropriate because the chance of incorrectly finding a significant difference increases with the number of comparisons. Multiple-comparison procedures are designed to provide an upper bound on the probability that any comparison will be incorrectly found significant.

As an example, the output from 'multcompare' for the lot-size independent variable for the dependent variable 'total nitrogen per hectare' is given below. Examination of the graphs clearly shows that 'very small', 'medium' and 'large' are all significantly different to each other as their confidence intervals don't overlap. 'Small' is significantly different to 'very small' (confidence interval doesn't overlap), but not significantly different to 'medium' or 'large' (confidence intervals overlap).

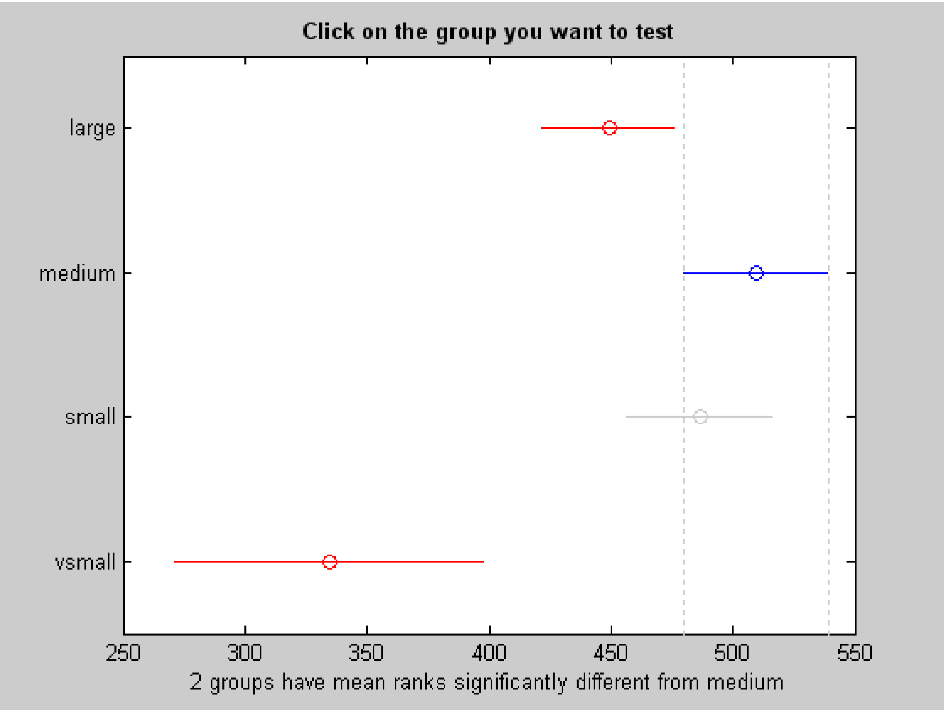
Output from 'multcompare' function for total nitrogen per hectare for different lot sizes

The 'multcompare' matrix for total nitrogen per hectare, grouped by lot size, is shown below. Each row of the matrix represents one test, and there is one row for each pair of groups. The entries in the row indicate the means of the ranks being compared, the estimated difference in these average group ranks, and a confidence interval for the difference. For example, the first row shows the mean rank of group 1 ('small') minus the mean rank of group 2 ('medium') is estimated to be -22.9850 and a 95% confidence interval for the true mean is [-83.0032, 37.0332]. Since the confidence interval contains 0.0, the difference is not significant at the 0.05 level. However, the third row shows the mean rank of group 1 ('small') minus the mean rank of group 4 ('very small') is estimated to be 152.0883 and a 95% confidence interval for the true mean is [58.8832, 245.2934]. Since the confidence interval doesn't contain 0.0, the difference is significant at the 0.05 level.

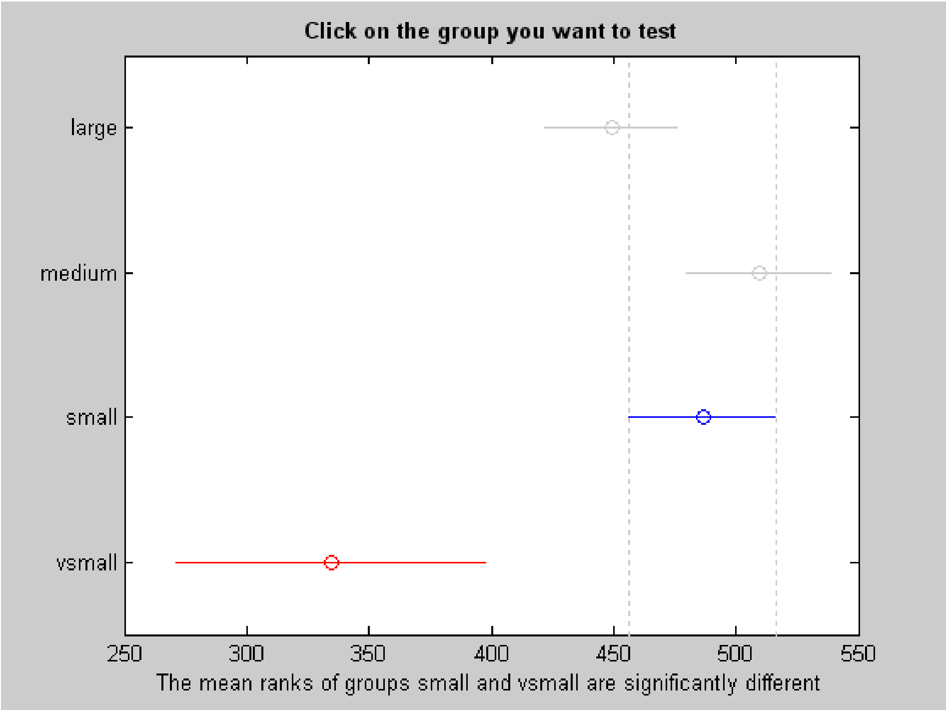
c =

1.0000	2.0000	-83.0032	-22.9850	37.0332
1.0000	3.0000	-19.7021	37.3945	94.4911
1.0000	4.0000	58.8832	152.0883	245.2934
2.0000	3.0000	3.3419	60.3795	117.4171
2.0000	4.0000	81.9043	175.0733	268.2423
3.0000	4.0000	23.3795	114.6938	206.0080

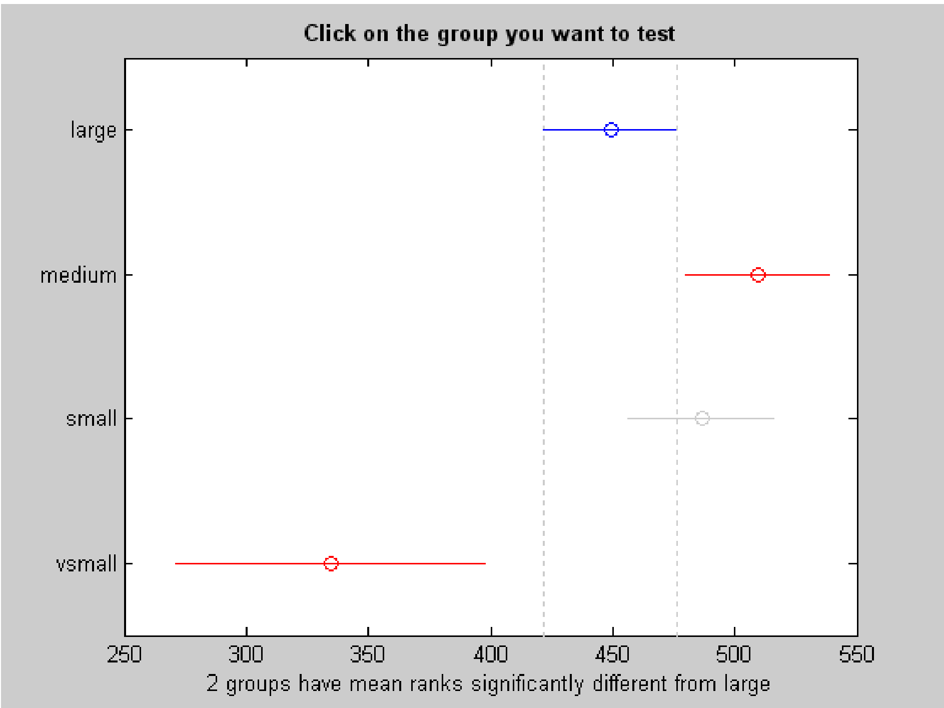
The interactive graphs produced by the ‘multcompare’ function are shown below. Each ranked group mean is represented by a symbol and an interval around the symbol. Two rank means are significantly different if their intervals are disjoint, and are not significantly different if their intervals overlap. The mouse is used to select any group, and the graph highlights any other groups that are significantly different to it.



‘Medium’ is significantly different to ‘very small’ and ‘large’, but not to ‘small’



'Very small' is significantly different to 'small', but not to 'large' and 'medium'



'Large' is significantly different to 'medium' and 'very small' but not to 'small'

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