

Chapter 3: Methods

3.1. Study area

3.1.1. Location

The city of Potchefstroom is situated in the North West Province in South Africa, between 27°04' and 27°07' longitude and 26°40' and 26°44' latitude. Potchefstroom is located in the Dry Sandy Highveld Grassland of the Grassland biome (Cilliers & Bredenkamp 1999; Mucina & Rutherford 2006). The mean annual rainfall in Potchefstroom is 620 mm with severe frost episodes during the winter months. Summer temperatures are high with a mean maximum temperature of 32°C, and cold in winter months with a mean minimum temperature of -1°C (Cilliers *et al.* 1998).

This study was conducted along the Spitskop Spruit, Wasgoed Spruit, and the Mooi River (hereafter called the “three streams”) situated within the Potchefstroom municipal area. Figure 3.1 is an aerial photo, and Figure 3.2 a map of Potchefstroom, showing the location and arrangement of the three streams. Spitskop Spruit and Vaalkop Spruit join one another to form the Wasgoed Spruit, as illustrated in Figures 3.2 and 3.3. Figure 3.1 displays the location of Potchefstroom Dam, Poortjie Dam, Ikageng (the former black township), the industrial area, the city centre, and O.P.M. Prozesky Bird Sanctuary in relation to the three streams. The locations of the Van der Hoff marshland and the Prozesky marshland along the Mooi River are also indicated and will be discussed later. Figure 3.2 demonstrates the urban infrastructure and development surrounding these three streams. The characteristics of the three streams are discussed in detail in Sections 3.2.1.1, 3.2.1.2 and 3.2.1.3, with references made to Figures 3.1, 3.2 and 3.3.



Figure 3.1 Aerial photograph of Potchefstroom.

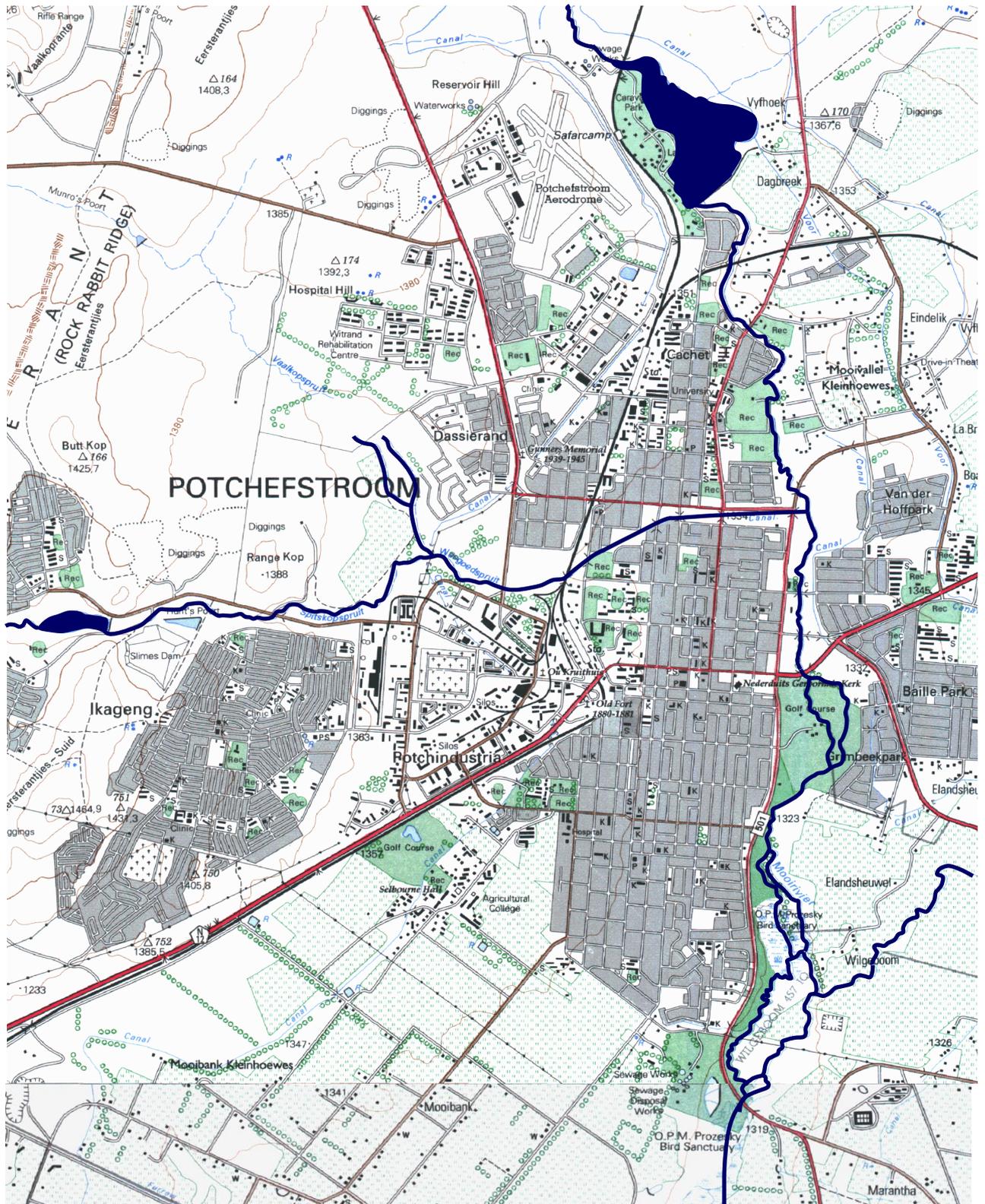


Figure 3.2 Map of Potchefstroom.

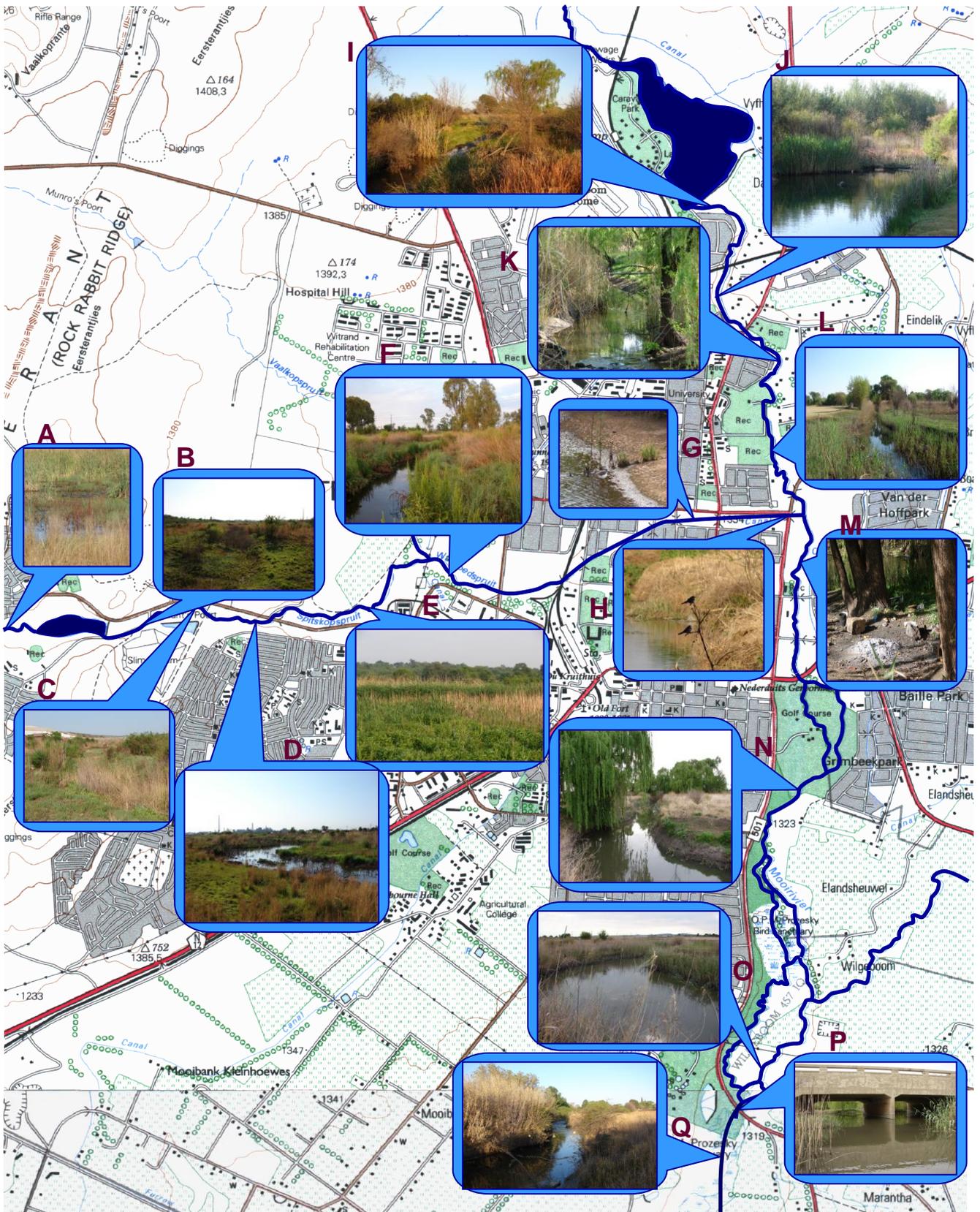


Figure 3.3 Map of Potchefstroom illustrating different sectors (indicated alphabetically) along the three streams.

3.1.1.1. Spitskop Spruit description

The Highveld National Park is situated west of Potchefstroom and borders Ikageng. Spitskop Spruit begins outside Ikageng, near the Highveld National Park and then flows into Poortjie Dam. This area (Sector A, Figure 3.3) drains the northwestern part of Ikageng into Spitskop Spruit and forms a small wetland area. Grass and reeds grow in the centre of the streams and they are the most abundant vegetation in this area.

Spitskop Spruit flows out of Poortjie Dam to the east, where it passes the eastern parts of Ikageng. Spitskop Spruit appears to be dryer within sectors B and C as it flows out of Poortjie Dam. The most dominant vegetation in these two sectors is herbs, shrubs, and grass. A few dirt roads that connect Ikageng to the main tar road are present in these areas.

Water drains from the southern parts of Ikageng into Sector D and flows further into another wetland area found in Sector E. Sector D is a transition between Sectors C and B (the dryer herb, shrub, and grassy areas) and Sector E (the reed and grassy area). Industrial activities south of Spitskop Spruit probably collect polluted water into Sector E. Spitskop Spruit joins Wasgoed Spruit north of the industrial area.

3.1.1.2. Wasgoed Spruit description

Spitskop Spruit flows into Wasgoed Spruit near the Industrial area of Potchefstroom. Water also drains into Wasgoed Spruit from the western parts of the city, which includes the industrial and natural areas and then flows into the Mooi River on the eastern part of the city. This stream consists mainly of three sectors. The first one indicated as Sector F (Figure 3.3) is natural, while Sector G is canalised by concrete. The natural Sector F is situated in a less transformed area and flows into the canalised section of the stream. The canalised concrete section (Sector G) of Wasgoed Spruit then flows through the residential areas of Potchefstroom, and runs through Sector H into the Mooi River.

The vegetation in the natural sector includes trees, shrubs, reeds, herbs, and grass. Two water canals run from the industrial area and connect with Wasgoed Spruit in Sector F. The most dominant vegetation in Sector G (canalised) are trees, shrubs and lawn along the stream. This sector is close

to houses and associated human activities such as walking, cycling, and transport. Littering occurs in this sector because of the nearby human activities. Sector H has a small wetland area with reeds and grasses along the stream.

3.1.1.3. Mooi River description

The Mooi River is a perennial stream, fed by a number of springs within and beyond the northern limits of the study area (Cilliers *et al.* 1998). The Mooi River flows out of Potchefstroom Dam in sector I (Figure 3.3). This sector has a combination of trees, shrubs, reeds and grass. From here, the river passes a retirement village, which is located in Sector J (Figure 3.3). Trees, shrubs, reeds and lawn are the combinations of vegetation types along this sector. Sector K has a high tree density with lawn along the Mooi River. These trees are 20 meters and taller, causing this part of the river to be very shady. Small patches of reed appear along this area and pass through a recreation park. Sector L occurs on the southern section of the recreational region and has a combination of shrubs and reeds along the stream. Informal settlers live along the Mooi River within sector M. The photo of Sector M (Figure 3.3) illustrates typical informal occupation along the stream. Vegetation such as trees, shrubs and reeds occur along this sector.

The N12 road from Johannesburg to Klerksdorp crosses the Mooi River between a golf course and a newly constructed shopping centre. This shopping centre is build across the Mooi River and is a significant anthropogenic alteration of the riparian system. The Mooi River splits into two streams entering the golf course and joins again at the southern part of the golf course. The river flows from the golf course into Sectors N, O and Q (Figure 3.3). Trees, shrubs, grass, herbs and reeds occur along these sectors.

A cattle farm with intensive grazing is present between Sectors N and O on the western and eastern side of the Mooi River. The O.P.M. Prozesky Bird Sanctuary is located within Sectors N, O and Q. Another cattle farm is located on the eastern side of the Mooi River, and the southern parts of O.P.M. Prozesky Bird Sanctuary. This farm is located on the western side of the Mooi River along Sector Q. The R501 road bridge crosses the Mooi River at Sector P (Figure 3.3).

Three main marshlands are part of the Mooi River; they are the Arboretum, Van der Hoff Park, and the Prozesky marshlands (Cilliers *et al.* 1998). The Van der Hoff Park and Prozesky marshlands can be seen in the aerial photograph of Potchefstroom (Figure 3.1) and fell within the scope of this study, but not the Arboretum. The Van der Hoff Park marshland is situated between two residential areas close to the city centre, but is heavily disturbed due to grazing, especially by horses (Cilliers *et al.* 1998). The O.P.M Prozesky Bird Sanctuary area stretches from nearby the city centre towards the southern municipal border. This marshland is heavily grazed by cattle and is characterised by deep depressions and drainage canals with higher-lying areas in between (Cilliers *et al.* 1998). The R501 road crosses the Prozesky Marshland. This municipal sewage plant is located on the western side of the Mooi River and consists of several dams with various vegetation types.

3.2. Bird survey techniques

Sequential transects ($n = 79$), each approximately 300 m in length, were located using a GPS (Geographical Positioning System) along the streams in the study area. The start, middle and end coordinates of each transect were recorded. Figure 3.4 is a map that illustrates the arrangement of transects along the streams. The light blue arrows indicate the downstream direction, and the numbering of the transects were done in the same direction. The Mooi River had 50 transects, Wasgoed Spruit 12 and Spitskop Spruit 17. Each transect is numbered sequentially from the first to the last transect along each stream.

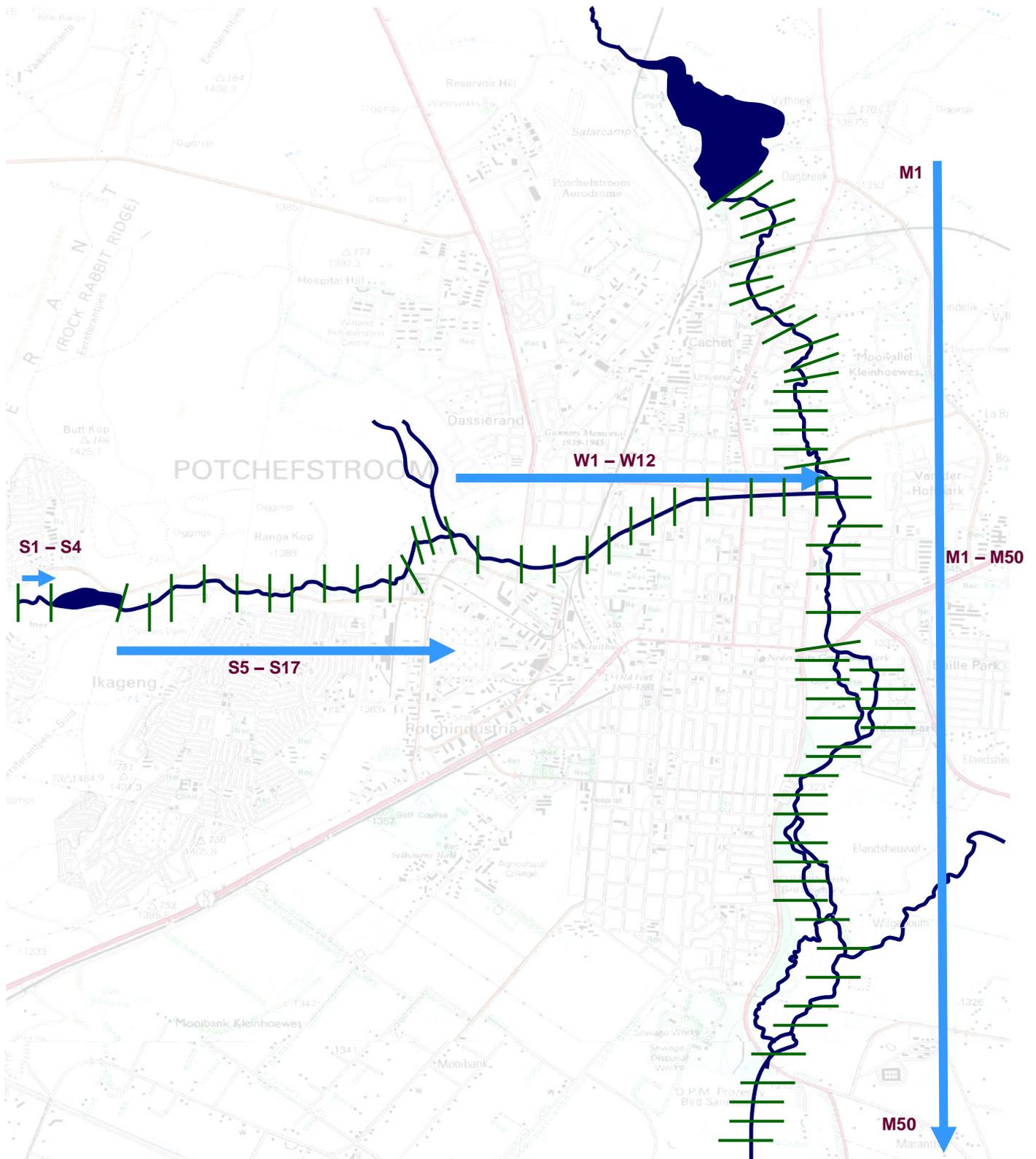


Figure 3.4 The arrangement of the 79 sequential transects along Spitskop Spruit (S1-S4 and S5-S17), Wasgoed Spruit (W1-W12), and the Mooi River (M1-M50).

The following materials were used for counting birds.

1. GPS
2. Compass
3. Binoculars
4. Laser range finder
5. Digital camera
6. Data sheets
7. Tape recorder
8. Bird identification guides

Bird counts were completed in each transect in the mornings by walking as close to the stream as possible in the downstream direction. Counts were done monthly in each transect from June 2006 until June 2007 (13 monthly counts). Birds and environmental factors were surveyed at a maximum perpendicular distance of 30 meters on both sides of the streams. Therefore, the total area of one transect is approximately 1.8 ha ($300\text{m} \times 60\text{m} = 18\,000\text{m}^2 = 1.8\text{ha}$). The transects were counted at different times of the day in consecutive months to prevent biased observations due to the time of day (early vs. late mornings).

Figure 3.5 illustrates the observation method used when counting birds and the method for determining the perpendicular distances of the birds. Perpendicular distances were determined to ensure the birds were counted in range of 30 meters from the streams.

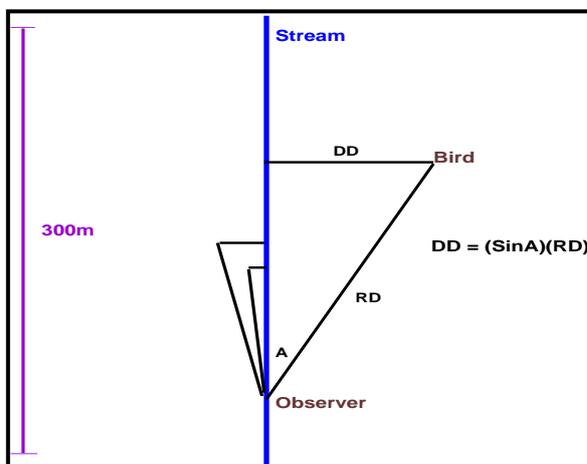


Figure 3.5 The bird counting method.

RD: Real distance, DD: Direct distance, A: Angle between the stream and RD.

Figure 3.5 shows a transect length which is 300 meters long and the blue line demonstrates the stream from where the observations were done. The RD (real distance) illustrates the distance (determined by a laser range finder, real distance) between the observer and the bird. "A" is the angle between the RD direction and the stream (transect). This angle was determined by using a compass. The perpendicular direct distance (DD, direct distance from the stream) was then calculated. Birds were only counted on sight, as most birds do not call in winter. The observer has previous experience with bird identification. Pictures were taken of birds that were difficult to identify. These birds were looked up in available bird guides and the supervisor was consulted for further confirmation. Species were named according to the Roberts Birds of Southern Africa (Hockey *et al.* 2005).

Smaller birds become less detectable with an increase in distance from the observer, at a rate faster than for larger birds (Bibby *et al.* 1993). Together with the changes in vegetation over time, it cannot be stated that observation conditions remained the same, and that some of the smaller species might have been missed or under-counted in some transects with variable vegetation. Correction for observability was considered (therefore the determination of RD and during the surveys). However, not enough data was gathered per habitat type per small species per season to do such conversions for small birds. The relatively narrow transect width (60m), as well as intensity and reproducibility of sampling, taken together, was considered robust enough for the main purpose of the study, namely the tracking of changes in avian communities over time.

3.3. Environmental factors survey method

As these three streams are located in an urbanised environment, they have a wide range of vegetation and anthropogenic structures presenting different kinds of avian habitats. An ecological profile was drawn for each transect to illustrate the differences. These ecological profiles consists of a cross-section of the streams for each transect, divided into five bands. The middle band was the stream channel (band A). The terrestrial areas include two bands on both sides of the canal, with 0-15 and 15-30 meter bands

parallel to the stream. Each band has an approximate area of 0.45 ha, and the layout of the cross-section is illustrated in Figure 3.6.

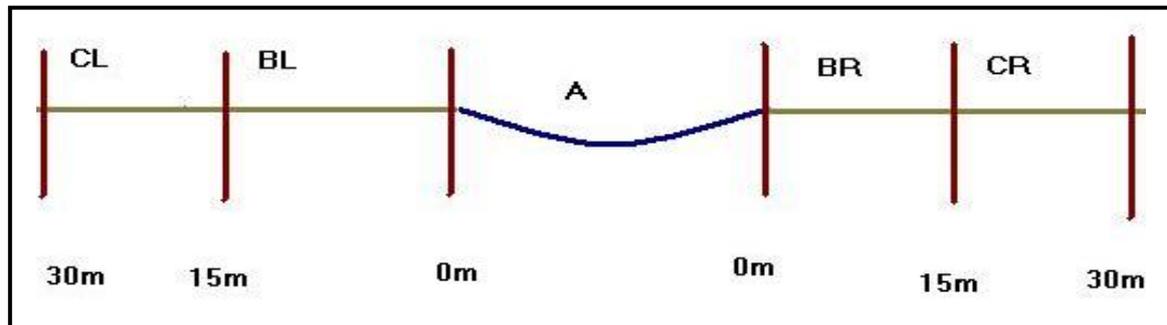


Figure 3.6 Cross-section illustrates the five bands in each transect. CL and BL are positioned on the left side of the stream, and BR and CR are positioned on the right side of the stream when looking downstream.

Environmental factors were surveyed in each band of all transects to identify and document habitats along the streams. These environmental factors included vegetation structure, anthropogenic factors and human social factors (presence of informal settlers).

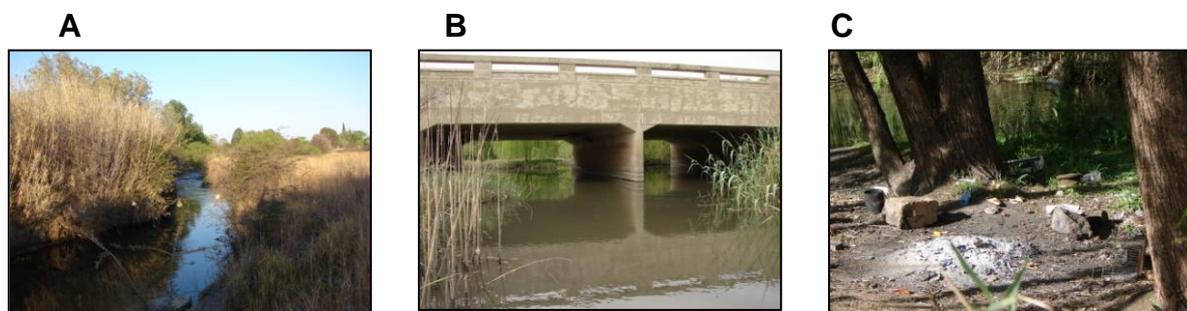


Figure 3.7 Images illustrating the environmental factors that were surveyed at each transect. A shows riparian vegetation structure, B shows anthropogenic factors such as this road bridge, and C shows human social factors (presence of informal settlers).

Broad-scale structural classifications of vegetation were used to determine the vegetation structure in each transect according to Edwards (1983). However, the system was adapted by the addition of sedges and reeds to the four vegetation classes (trees, shrubs, reeds and herbs) that Edward (1983) used. Therefore, the broad-scale structural classification system of vegetation compiled by Edwards (1983) was inadequate, and needed to be adapted in

order to characterise avian habitats in the riparian corridors. Consequently, the vegetation was divided into six main vegetation types: trees, shrubs, grasses, herbs, sedges and reeds. The height and cover percentages of each type were estimated in each band (Figure 3.6) of all transects. The different height and cover classes are given in Tables 3.1, 3.2, and 3.3.

Due to the effect of seasonal changes on vegetation structure, two vegetation structure surveys were completed: one during summer (from February 2007 to April 2007) and one during winter (from June 2007 to August 2007).

River ecological profiles of each transect of the summer and winter vegetation structures were drawn according to the cross-section in Figure 3.6. These river ecological profiles demonstrate the vegetation structures in each transect and are represented in Appendix A. These river ecological profiles (Appendix A) illustrate the height and cover percentages of the six main vegetation classes.

However, a categorical scale for the vegetation structure is needed to perform multivariate analyses. These different categorical scales are shown in Tables 3.1, 3.2 and 3.3.

Table 3.1 Different height classes of trees (Edwards 1983).

	Categorical scale	Tree height (m)
High	7	> 20m
Tall	6	10 – 20m
Short	5	5 – 10m
Low	4	2 – 5m

Table 3.2 Different height classes of shrubs, grass, herbs, sedges and reeds (Edwards 1983).

	Categorical Scale	Shrubs	Grass	Herbs	Sedges	Reeds
High	4	2 – 5m	> 2m	> 2m	> 2m	> 2m
Tall	3	1 – 2m				
Short	2	0.5 – 1m				
Low	1	< 0.5m				

Table 3.3 Different cover classes of trees, shrubs, grass, herbs, sedges, and reeds (Edwards 1983).

	Categorical scale	Cover classes
Continuous	7	100 – 76%
Sub-continuous	6	75 – 51%
Moderately closed	5	50 – 26%
Semi-open	4	25 – 11%
Open	3	10 – 1%
Sparse	2	1 - 0.1%
Scattered	1	< 0.1%

Anthropogenic factors included the following: canalised concrete riverbeds, houses, road bridges, footpath bridges, footpaths, roads, electrical pylons and drainage pipes. The percentage cover of the anthropogenic factors was estimated in each band for all transects. The cover percentages of anthropogenic factors (man-made structures and informal settlers) were calculated for each band by dividing by 0.45 ha. These cover percentages were grouped into two cover classes with a categorical scale, which was used for multivariate analysis.

Table 3.4 The different cover classes of the anthropogenic factors.

Categorical Scale	Cover Classes
2	25 – 11%
1	10 – 1%

The number of homeless people living alongside the streams may have an adverse effect on species richness, abundance and distribution. The actual number of informal settlers living in these areas could not be determined accurately, as these areas are only used as a temporary residence at night. However, an estimated number of people and the percentage of space they occupied were determined for each band in the transects where they lived.

The occupied space was determined by measuring the radius of the occupied area. The occupied space was then converted to percentage of occupied space by dividing the radius with 0.45 ha (Figure 3.6). The categorical scale of the occupied space and the average number of people in each band of all transects were used for multivariate analysis. The anthropogenic factors were surveyed in conjunction with the bird surveys from June 2006 to June 2007.

Table 3.5 The different cover classes for the occupied space of the informal settlers.

Categorical Scale	Cover Classes
2	25 – 11%
1	10 – 1%

The environmental factors were assigned with categorical values according to Tables 3.1, 3.2, 3.3, 3.4, and 3.5. These factors were measured in different variables (cover and height classes) and units (example trees, shrubs, grass, reeds, herbs, bridges, roads, etc.), yet they had to be analysed together. To solve this problem, data was relativised in order for the quantity of each vegetation type and anthropogenic factor to be expressed as a proportion of the maximum unit (McCune & Grace 2002). This was done by using PcOrd (Version 5 – MjM Software, (McCune & Mefford 1999a)). This relativisation process adjusts matrix elements by row or column as appropriate (McCune & Grace 2002). In this study, matrix elements consisted of vegetation and anthropogenic categorical values within each transect. The categorical values were relativised across each column. With this data treatment, environmental data could be used appropriately in multivariate analysis. The methodology of the multivariate analysis is discussed in Section 3.5.

3.4. Data analyses: Transect-time profiles

The motivation for the transect-time profiles was to visually represent changes of the following four parameters on spatio-temporal scales along the three streams: relative avian density (RAD), species richness, Shannon-Wiener diversity index and total avian biomass (TAB). However, before these

transect-time profiles could be drawn, the following data treatments had to be done.

The avian data for each month (June 2006 to June 2007) was entered into Excel (Microsoft) spreadsheets. Avian abundance, RADs, species richness and TABs were determined for each month using Excel. The same avian data was analysed with Primer 5 software (Version 5.2.9) (Clarke & Gorley 2006) to obtain the Shannon-Wiener diversity for each month.

Four parameters were used to draw transect-time profiles.

1. RAD was calculated for each transect by dividing the avian abundance by 1.8 ha (area of one transect) to provide abundance per hectare.
2. Species richness was the number of observed species within each transect.
3. The Shannon-Wiener diversity index combines species richness and abundance to determine diversity levels and was calculated using Primer 5 software (Version 5.2.9, Clarke and Gorley (2006)).
4. The mean body mass of each bird species was obtained from Hockey, *et al.* (2005). These body mass values are listed in Table 4.2. The total avian biomass (TAB) per hectare was then calculated for each species within all transects per month.

Transect-time profiles were constructed using Microsoft Excel. The transect-time profiles illustrate the monthly changes of the four parameters for each month (June 2006 to June 2007) along the three streams.

3.5. Data analyses: Multivariate analyses

Given the complexity of the data (13 monthly surveys of 156 species in 79 transects = 160 000+ records) and since the transects were consecutive and not independent (pseudo-replication), only summarised univariate statistics (totals, means, etc) are appropriate. To ascertain the avian community dynamics, extensive use was therefore made of multivariate statistics. Multivariate statistics used were one-way cluster analyses, non-metric multidimensional scaling (NMS), and indicator species analysis using PcOrd (Version 5, (McCune & Mefford 1999a)). PcOrd was also used to construct a species-area curve in order to determine whether enough transects were surveyed.

3.5.1. One-way cluster analysis

Cluster analysis define groups of items based on their similarities (McCune & Mefford 1999b). The environmental factors (summer vegetation structure and anthropogenic factors) were defined in different groups or clusters according to their similarities. The Sorensen (also known as Bray & Curtis) distance measurement was used.

Cluster analysis provides a dendrogram that shows the resulting hierarchy of clusters (McCune & Mefford 1999b). “Flexible Beta” was the linkage method to link similar groups. This linkage method is flexible because the user can control its space-distorting properties (McCune & Grace 2002). Flexible beta is also compatible with the Sorensen distance measurement (McCune & Mefford 1999b) and a beta-value of “-0.1” was used.

As seen in the previous paragraph, one of the results of cluster analysis is a cluster dendrogram. The “Information Remaining (%)” within a dendrogram was applied to prune (cut) the dendrogram. The position of the cut defined the number of resulting groups (McCune & Grace 2002).

For the summer vegetation structures and anthropogenic factors (together summer environmental factors), a 38% cut-off point was selected to characterise different clusters or groups of transects. A 50% cut-off point was selected for the anthropogenic factors (excluding summer vegetation). These points were selected in order to identify distinctive groups of transects, of which each were associated with particular environmental factors. The characterised groups of transects represent different characterised avian habitats (CAHs).

3.5.2. NMS (Non-metric multidimensional scaling)

NMS was used throughout this project as it is well suited for discontinued and heterogeneous data (McCune & Mefford 1999b). NMS avoids the assumption of linear relationships among variables, uses rank distances and minimises the error produced by the “zero-truncation” (absence) problem that is common to community data (McCune & Mefford 1999b). The Sorensen (Bray & Curtis) distance measurement was used to measure the distance between the objects in the n -dimensional hyperspace for an NMS. The NMS was done with 50 runs of real and randomised data.

Two and more dimensions (axes) can be derived from NMS ordination, and the appropriate number of dimensions are determined by plotting final stress versus the number of dimensions (McCune & Mefford 1999b). The dimensionality is selected by comparing the final stress values among the best solutions, one best solution for each dimensionality (McCune & Mefford 1999b). The best solution is the one with the lowest final stress from a real run (McCune & Mefford 1999b). Additional dimensions are considered useful if they reduce the final stress by 5 or more (on a scale of 0-100). PcOrd selects the highest dimensionality that meets this criterion (McCune & Mefford 1999b). However, graphics in PcOrd are limited to three axes, and for the current study, only two of the three dimensions were selected for representation of the NMS graphs.

The number of dimensions, final stress, and the percentage coefficients of determination for the correlations between ordination distances in the original n-dimensional space are given at each of the NMS graphs (Chapter 4). The two dimensions with highest percentage coefficients were selected for representation of the NMS graphs (Chapter 4).

Two types of NMS plots were used in this study; these were bi-plots and successional vector plots. A bi-plot represents sample units and variables in a single diagram. Successional vectors can be used in any case where a number of sample units have been followed through time (McCune & Grace 2002). The bi-plots showed the ordination of the transects (sample units) with the environmental factors (variables) (listed in Section 3.3). Successional vector plots were used to illustrate temporal changes of vegetation structures and avian communities.

The changes between summer and winter vegetation structures were illustrated in an NMS successional vector plot for the 79 transects. The vectors therefore connect the summer vegetation coordinate of each transect with its corresponding winter coordinate. The direction and the lengths of each vector indicate the direction and magnitude of vegetation changes from summer to winter. The only example is provided in Figure 4.10.

Transects and environmental factors were ordinated using NMS and presented in bi-plots. The vectors represent the environmental factors, and are labelled according to the vegetation types or anthropogenic factors. The

labelling of the vegetation types also include the band name (locations of the vegetation, Figure 3.6), and the cover or height variables of the vegetation types. Transects within the same cluster were circled by using the cluster dendrograms (Section 3.5.1 and an example in Figure 4.11). These clusters define the different CAHs that were identified from the cluster dendrograms (Section 3.5.1). The vectors in the NMS bi-plot associated with each CAH indicated the dominant environmental factors and the CAHs were named according to these factors.

Distribution maps on these CAHs, illustrated in Appendix B, were drawn using GS+ software (Version 7, (Anon 2004)). These maps and the different sectors (Figure 3.3) demonstrate the distributions of CAHs within the different sectors.

Successional vectors were used to illustrate temporal changes of avian communities (avian community trajectories) from June 2006 to June 2007. Avian data of each CAH during each month were ordinated using NMS. Each CAH, therefore, has thirteen (monthly) coordinates. Twelve successional vectors connect the thirteen coordinates of each CAH. The lengths of the vectors from one month to the next for a specific CAH indicate the magnitude of avian community changes relative to all other vectors and CAHs. The twelve successional vectors of each CAH represent its avian community trajectory over time. Note that the abbreviated common English names of the species are listed in Table 4.1.

3.5.3. Indicator species analysis

Indicator species analysis was performed with PcOrd to detect and describe the value of different species for indicating environmental conditions (McCune & Grace 2002). For the purpose of this study, a non-hierarchical indicator species analysis was performed to describe associations of species with the different CAHs. Observed indicator values (IVs) were generated by the analysis and explain the percentage of perfect indication. These IVs were obtained by combining the relative abundance and relative frequencies of the birds counted in each CAH. IVs are then tested for statistical significance by using a randomisation technique (Monte Carlo), producing a mean, standard

deviation and P-value (McCune & Grace 2002). A thousand randomisations (default setting in PcOrd) were used in the Monte Carlo test.

Due to, a large number of species that have $P \leq 0.0030$, (Tables 4.3 and 4.4), species were recognised as indicator species when they had a $P \leq 0.0030$.

3.5.4. Multivariate analyses for the nesting and feeding guilds

Species were classified into seventeen nesting and eight feeding guilds (Table 4.2) according to their nesting behaviours (preferred nesting sites) and feeding preferences, obtained from Hockey *et al.* (2005). A guild is a grouping of species with similar ecological functions, as discussed in Section 1.1.5.

The seventeen nesting guilds were; extralimital-breeding (non-breeding migrants in Southern Africa), tree-nesting, tree/shrub-nesting, shrub/grass-nesting, reed-nesting, reed/shrub-nesting, cavity/tree-nesting, cavity-nesting, ground/grass-nesting, tree/reed-nesting, structure-nesting, structure/tree-nesting, shrub-nesting, grass-nesting, grass/reed-nesting, ground-nesting, and parasitic species. For this study, cavity/tree-nesting species (Table 4.2) included those that utilise cavities within trees.

The species within the following nesting guilds were separately ordinated with the coordinates (thirteen months) of the summer CAHs, and presented in NMS successional vector plots in Section 4.4.3:

- Tree-nesting guild
- Tree/shrub in combination with shrub-nesting guild
- Tree/reed-nesting guild
- Grass/reed in combinations with grass and reed nesting guilds
- Shrub/grass in combination with shrub/reed-nesting guild
- Ground in combination with ground/grass-nesting guild
- Parasitic breeders
- Cavity in combination with cavity/tree-nesting guild
- Structure/tree in combination with structure-nesting guild

Several nesting guilds only consisted of a few species, and therefore, some of these nesting guilds were combined within the NMS successional vector plots.

The different feeding guilds were; omnivores (a variety of food), herbivores (plant material), insectivores (insects), frugivores (fruit), granivores (seeds), carnivores (animals), scavengers (carrion), and insect/nectar feeding birds (insects and nectar). The majority of species were classified as insectivores, granivores, carnivores and omnivores. Therefore, the species within these four feeding guilds were selected for multivariate analysis. The species within these four feeding guilds were separately ordinated with the coordinates (thirteen months) of the summer CAHs, and presented in NMS successional vector plots in Section 4.4.4.