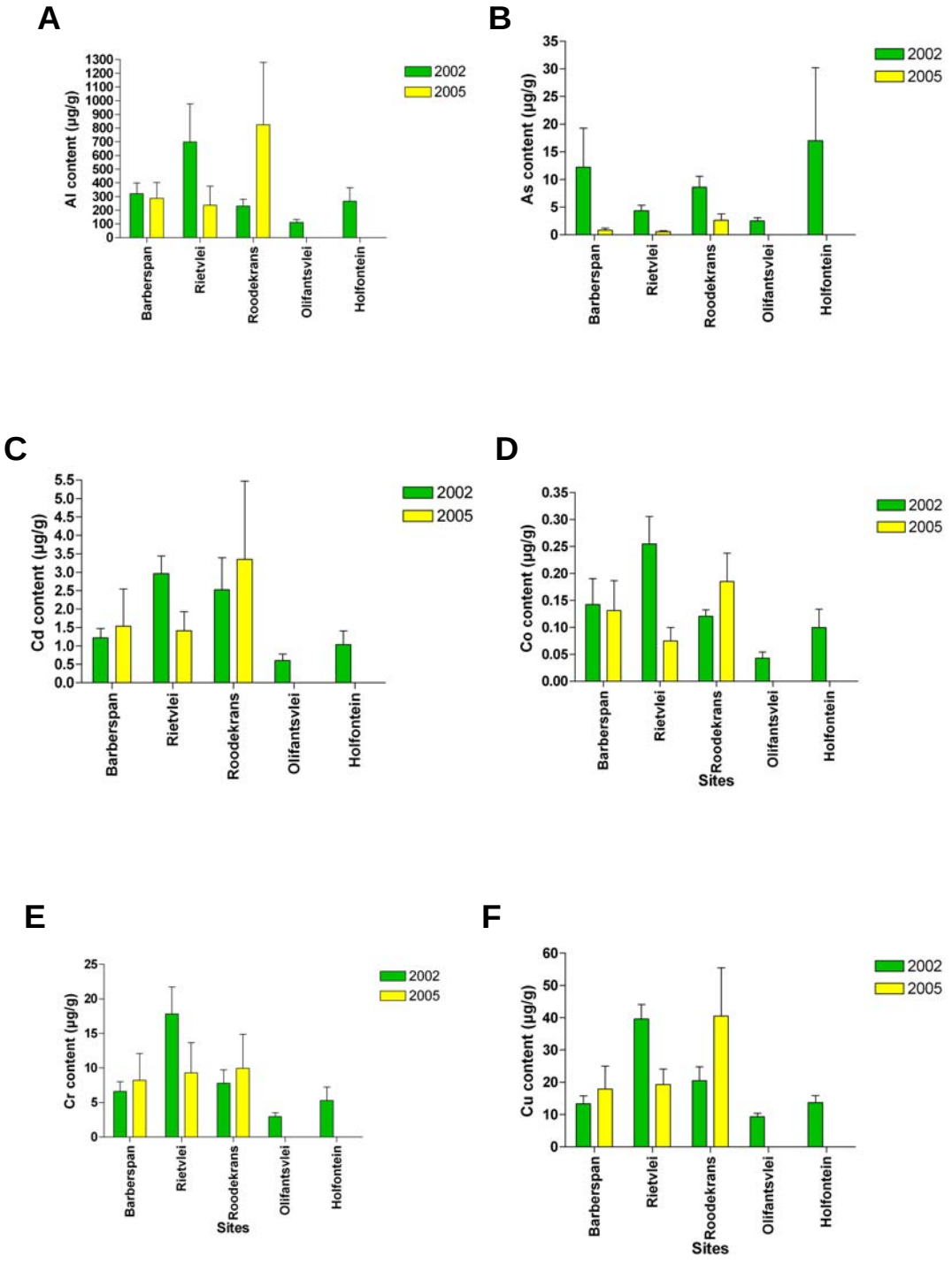
CHAPTER 4 - SPATIAL AND TEMPORAL VARIATION IN THE METAL LEVELS

4.1 Results

The results of the metal content in the feathers are summarized in Figures 4.1 and 4.2. All values are represented as mean + standard error and the significant differences were determined using ANOVA and Mann-Whitney U-Test ($p < 0.05$). Some general patterns of the metal content at the various sites for both surveys could be seen. For Al (Fig. 4.1A), Cd (Fig. 4.1C), Co (Fig. 4.1D), Cu (Fig. 4.1F), Fe (Fig.4.2A) and Pb (Fig. 4.2D) Rietvlei had the highest content in 2002 and Olifantsvlei the lowest. During the 2005 survey Roodekrans had the highest content and Rietvlei either had the lowest or was very similar to Barberspan. The metal content was similar during both sampling trips for most of the metals. There was only a significant difference ($p < 0.05$) in 2002 between Rietvlei and all the other sites for Cu and between Rietvlei and Barberspan, Rietvlei and Olifantsvlei and Rietvlei and Holfontein for Cd. There were no significant differences ($p < 0.05$) between the metal contents at the sites during the 2005 survey. There was a significant difference ($p < 0.05$) between the levels of Cd, Cu, Co and Fe at Rietvlei between the two surveys, with the 2002 survey having significantly higher levels.

The As content (Fig. 4.1B) was the highest at Holfontein and the lowest at Olifantsvlei in 2002. In 2005 the highest As content was at Roodekrans and the lowest at Rietvlei. There was no significant difference ($p < 0.05$) between the sites during both surveys. The values recorded for the 2005 survey was lower than the values for 2002. There was a significant difference ($p < 0.05$) between the values recorded in 2002 and 2005 at Rietvlei and Roodekrans.

As can be seen in Figure 6.1E the Cr content was the highest in Rietvlei in the 2002 survey and the lowest at Olifantsvlei. There was a significant difference ($p < 0.05$) between Barberspan and Rietvlei and Rietvlei and Olifantsvlei.



	Barberspan	Rietvlei	Roodekrans	Olifantsvlei
Rietvlei	Cd; Cr; Cu			
Roodekrans	-	Cu		
Olifantsvlei	-	Cd; Cr; Cu	-	
Holfontein	-	Cd; Cu	-	-

Figure 4.1 The levels of Al (A), As (B), Cd (C), Co (D), Cr (E) and Cu (F) in the feathers of weavers at selected sites in Gauteng and Northwest. The matrix shows the metals for which there was a significant difference ($p < 0.05$) in 2002. There were no significant differences ($p < 0.05$) in 2005 between the levels of the various metals at the sites.

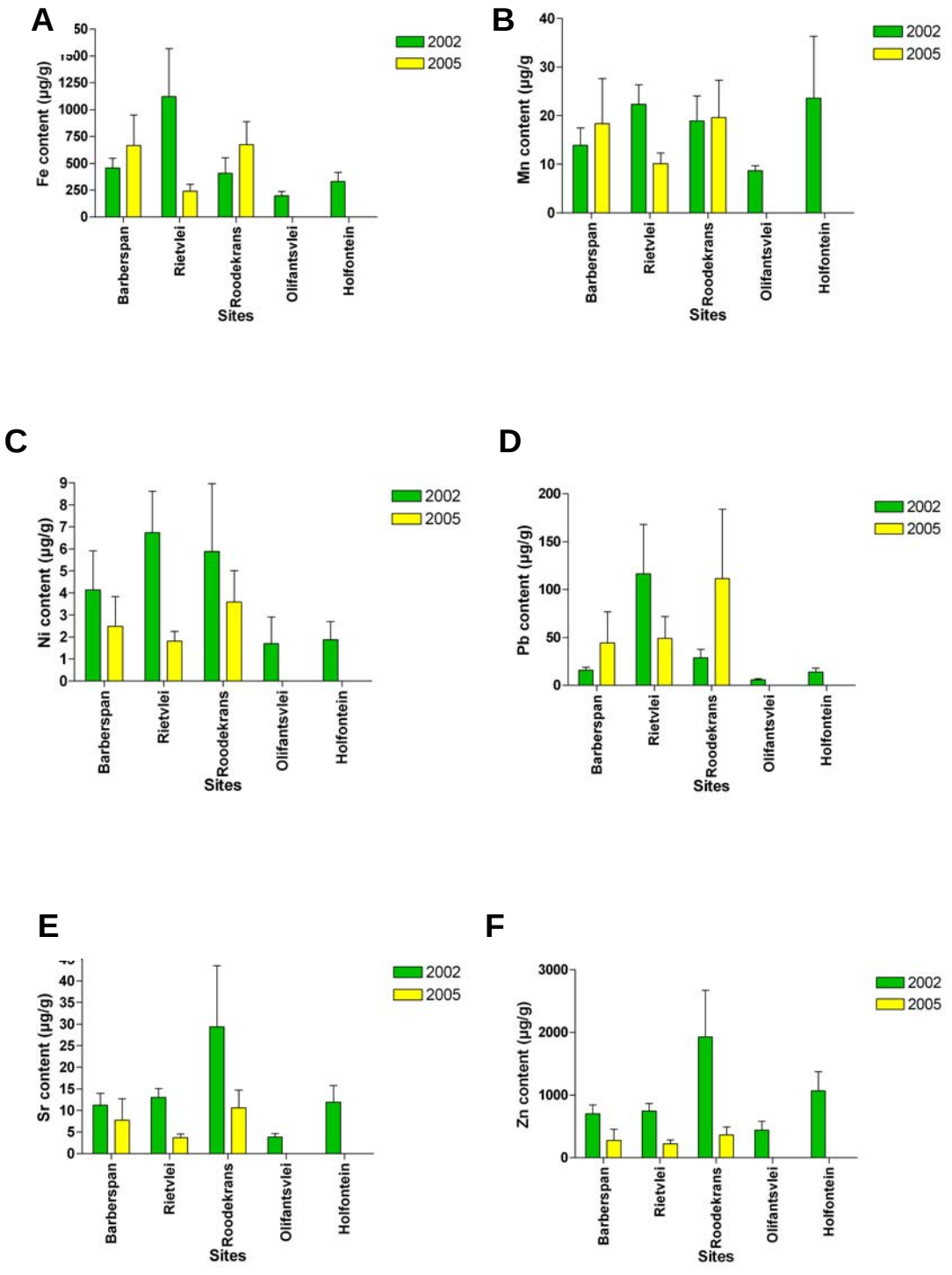


Figure 4.2 The levels of Fe (A), Mn (B), Ni (C), Pb (D), Sr (E) and Zn (F) in the feathers of weavers at selected sites in Gauteng and Northwest. There were no significant differences ($p < 0.05$) in 2005 between the levels of the various metals at the sites.

The highest Cr content was recorded at Roodekrans in 2005 and the lowest at Barberspan. There was no difference in 2005 between the sites and also no temporal difference ($p > 0.05$) at the sites.

There was no clear pattern for Mn (Fig. 4.2B). Holfontein had the highest level in 2002 and Olifantsvlei the lowest. In 2005 Roodekrans had the highest level and Rietvlei the lowest. There was no difference between the sites for both surveys. There was a significant difference ($p < 0.05$) however between the Mn content of the two surveys at Rietvlei. The highest values recorded for the Ni content was at Rietvlei in 2002 and Roodekrans in 2005 (Fig 4.2C). The lowest values were at Olifantsvlei in 2002 and Rietvlei in 2005. The only significant difference was at Rietvlei, where the 2005 value was significantly lower than the 2002 value. Strontium (Fig. 4.2E) and Zn (Fig. 6.2F) followed the same pattern. In the 2002 survey Roodekrans had the highest levels and Olifantsvlei the lowest. In 2005 Roodekrans had the highest and Rietvlei the lowest. There was no significant difference ($p < 0.05$) between the sites for both surveys. There was a significant difference ($p < 0.05$) between the two surveys for Sr at Rietvlei and Zn at Rietvlei and Roodekrans.

Multivariate analysis based on Bray-Curtis similarity coefficients and group averaged sorting (Bray and Curtis, 1957) was performed on the data using the PRIMER (Plymouth Routines in Marine Environmental Research) program v4.0, (Plymouth Marine Laboratory). The metal content data from the different sites and sampling sites were analysed together. Cluster analysis and multi-dimensional scaling (MDS) (Kruskal and Wish, 1978) were performed on the averaged data of each individual biomarker test for every site. Multivariate analysis techniques are potentially a useful tool for interpreting bioaccumulation data as they produce a two-dimensional pattern of the degree of similarity between different groups of data based on bioaccumulation patterns. For the averaged data the stress value (a measure of the accuracy of the results) of 0.01 was obtained, indicating that the ordination is an accurate description of the temporal bioaccumulation patterns (Clarke and Warwick, 1994). Based on the multivariate analysis, two distinct groupings can be distinguished (Figure 4.3 A and B). The group I consists of Barberspan 2005, Rietvlei 2002 and 2005 and Roodekrans 2005.

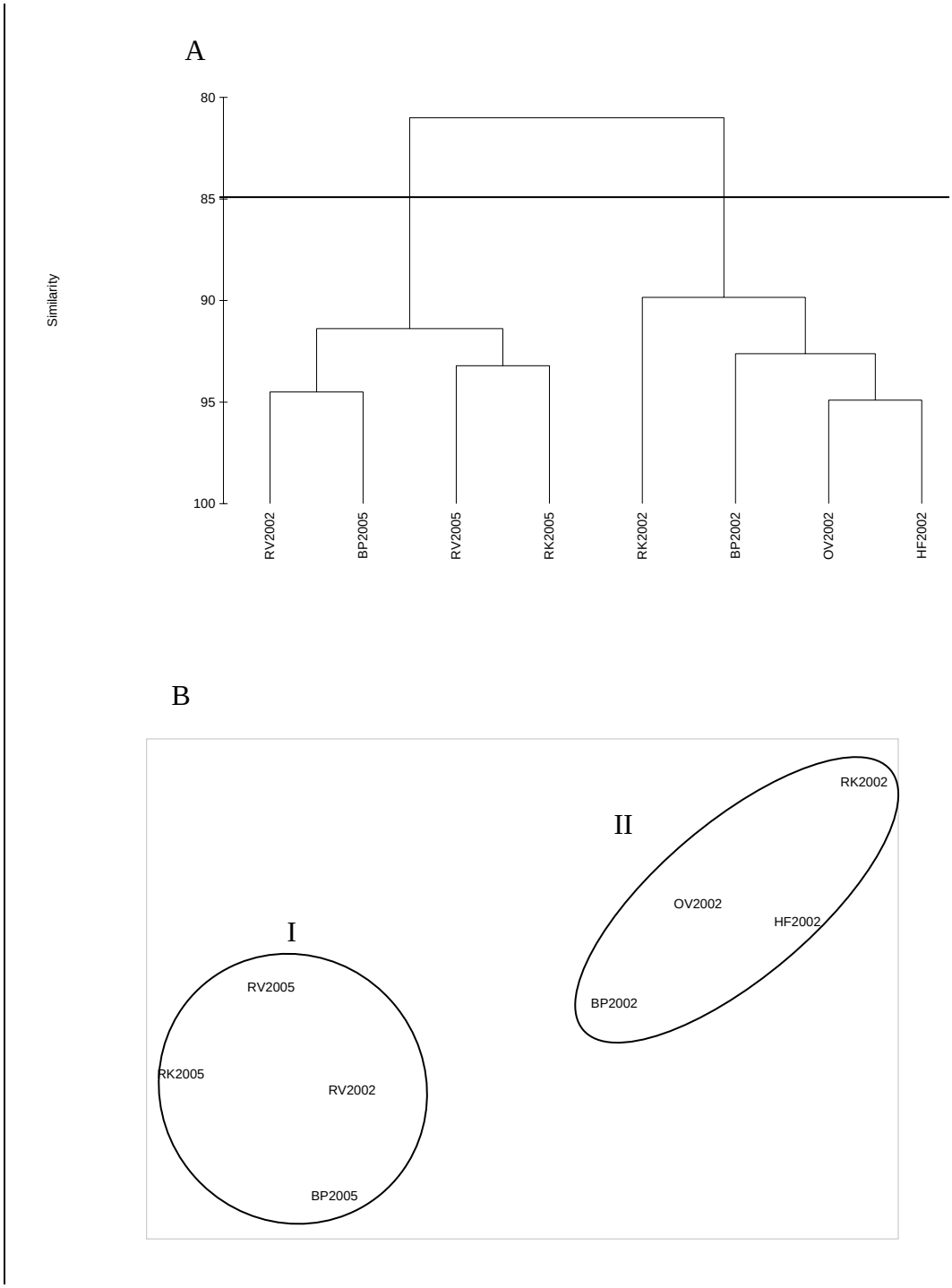


Figure 4.3 Dendogram (A) and MDS plot (B) constructed from multivariate analysis of the metal content at each site based on the similarities between the sites. Groupings were made at a similarity level of 85.

The other group (II) consists of Barberspan 2002, Roodekrans 2002, Olifantsvlei 2002 and Holfontein 2002. There were higher metal levels in the 2005 survey than in the 2002 survey, except for Rietvlei in 2002.

4.2 Discussion

4.2.1 Aluminium

Not a lot of information is available on the Al content in passerine feathers. The levels at all sites were very high in comparison to Blue Tits (Eens *et al.*, 1999), Great Tits (Eens *et al.*, 1999; Janssens *et al.*, 2001) and American Dippers (Morrissey *et al.*, 2005). The average Al content in Blue Tit feathers from a reference site was similar to the Al content at Barberspan in 2002. This site however was on an island of volcanic origin and had natural high levels of Al (Eens *et al.*, 1999). Janssens *et al.*, (2001) could not find a significant difference in the Al content of Great Tit feathers between sites along a pollution gradient. There is also no significant difference between the sites of this study. All the Al values obtained in this study were very high, which may point to Al pollution.

4.2.2 Arsenic

The levels of As were not detectable in Common Raven (*Corvus corax*) (Burger, 1993). The levels of As were in the same range as those recorded for Great Tits in Belgium (Janssens *et al.*, 2001) and Black-billed Magpies in Poland (Dmowski, 1999). The highest values recorded in this study (Holfontein 2002) correspond to values for Great Tits close to a pollution source (Janssens et al., 2001) and for Black-billed Magpie at a copper smelter in Poland (Dmowski, 1999). The lowest value (Rietvlei 2005) is similar to the value furthest away from the pollution source for Great Tits in Belgium and to values for the Black-billed Magpie in national parks in Poland. The lower levels of the 2002 survey and the levels of the 2005 survey correspond to levels for the Great Tit in Belgium (Dauwe *et al.*, 2000). The levels from Barberspan and Rietvlei in the 2005 survey were similar to levels recorded for Sand Martins in Hungary (Vallner *et al.*, 2000). Thus the sites can be grouped into high As content (Barberspan 2002 and Holfontein 2002), medium As content

(Rietvlei 2002, Roodekrans 2005 and Olifantsvlei 2002) and low As content (Barberspan 2005 and Rietvlei 2005).

4.2.3 Cadmium

The levels of Cd was in the same range as levels in the feathers of Sand Martins from Hungary (Vallner *et al.,* 2000) and various tit species (Family Paridae) (Sawicka-Kapusta *et al.,* 1986) from Poland. The levels were however a lot higher than those found in American Dippers (Morrissey *et al.*, 2005). The levels of Cd in this study were a lot lower than feathers of Black-billed Magpie near a zinc smelter in Poland, but higher those from the reference areas of the study (Dmowski, 1999). The Cd values for Olifantsvlei and Holfontein in 2002 were similar to values obtained form reference sites in Belgium for tits in Belgium. The values from Rietvlei 2002 and Roodekrans (both 2002 and 2005) were similar of higher than values from polluted sites from the above mentioned study (Eens *et al.,* 1998). The values obtained in this study also correspond to values along a pollution gradient in Belgium for Great tit feathers (Janssens *et al.,* 2001). According to all this, the sites can be grouped into high Cd content (Rietvlei 2002, Roodekrans 2002 and 2005), medium Cd content (Barberspan 2002 and 2005 and Rietvlei 2005) and low Cd content (Olifantsvlei 2002 and Holfontein 2002). It must be kept in mind however that the highest values in this study are still much lower than values from polluted sites.

4.2.4 Cobalt

Not a lot of studies have been done on Co, especially on passerines. Most of the values obtained were similar to those found in Belgium for tits (Janssens *et al.,* 2001). According to this study the sites can be grouped in to medium Co content (Barberspan 2002 and 2005, Rietvlei 2002 and Roodekrans 2002 and 2005) and low Co content (Rietvlei 2005, Olifantsvlei 2002 and Holfontein 2002). The Co content in feathers of Sand Martins in Hungary was however a lot higher than those in this study (Valner *et al.,* 2000). Although not a lot of data is available, it seems that the levels of Co in this study area are relatively low.

4.2.5 Chromium

The values were mostly higher than values obtained for Black-billed Magpie in Poland (Dmowaski, 1999) and Great Tits in Belgium (Janssens *et al.,* 2001). They

were however in the same range as values obtained for several passerines in Papua New Guinea (Burger, 1993). Although Cr comes from natural sources, its main sources are anthropogenic activities like mining (Burger, 1993). The values obtained from Rietvlei in 2002 are even higher than those of Black-billed Magpie from near a chromium smelter (Dmowski, 1999). This indicates that there are very high levels of Cr at all the sites and Cr pollution might be occurring.

4.2.6 Copper

Copper is an essential element and enters the environment through various industrial and commercial processes (Burger, 1993). The levels of Cu were a lot higher than values obtained for Common Ravens in California, USA (Burger, 1993). Most of the values from this study were in the same range as those founds for Great Tits in the middle of a along a pollution gradient in Belgium (Janssens *et al.*, 2001). The values were higher than those for Great and Blue Tits from polluted and unpolluted sites in Belgium (Eens *et al.,* 1999). The values obtained from Rietvlei 2002 and Roodekrans 2005 were however higher, but lower than values obtained for tits from polluted sites in Belgium (Dauwe *et al.,* 2002). The values in this study were again mostly higher than those for tit nestlings in Belgium (Dauwe *et al.,* 2000; Dauwe *et al.,* 2004) and American Dippers in Canada (Morrissey *et al.*, 2005). The levels were mostly a bit higher than levels for tits in Poland (Sawick-Kapusta *et al.,* 1986), but in the same range as those for Black-billed Magpie in Poland (Dmowski, 1999). Only the values from metal smelters were a lot higher than in this study. Based on previous studies we can group the sites as having high Cu content (Rietvlei 2002 and Roodekrans 2005) and medium Cu content (Barberspan 2002 and 2005, Rietvlei 2005, Roodekrans 2002, Olifantsvlei 2002 and Holfontein 2002). It must be noted however that values obtained from pollution sources are much higher than those from the two sites classified as high Cu content in this study.

4.2.7 Iron

There was a huge difference between the levels of Fe between the sites and between surveys. The lower values obtained in this study are similar to values for several tits species from Poland (Sawick-Kapusta *et al.*, 1986). The highest value, recorded at Rietvlei in 2002, corresponds to the level of Fe in the feathers of Sand Martins in Hungary (Vallner, 2000). All the values recorded were higher than values for Fe in

the feathers of Great Tits in Belgium along a pollution gradient (Janssens *et al.*, 2001) and pigeons in Czechoslovakia (Burger, 1993). Thus all the sites can be classified as high Fe content, with Rietvlei 2002 as very high.

4.2.8 Manganese

There are not a lot of data available on the level of Mn in Passerines. The Mn levels from this study were similar to the lower values recorded for Great Tits in Belgium, but lower than the highest values (Janssens *et al.,* 2001). The values were lower than those for Sand Martins in Hungary (Vallner *et al.,* 2000), but higher than those for several passerine species from Papua New Guinea (Burger, 1993) and American Dippers in Canada (Morrissey *et al.,* 2005). Although there are not a lot of data available, all the sites can be grouped as Medium Mn Content.

4.2.9 Nickel

The Ni content from both surveys during the study is higher than those for nestling Great Tits (Dauwe *et al.,* 2004). This is likely due tot the fact that the nestlings were not exposed to contamination as long as the adult birds used in this study. The values were also similar or higher than values from Great Tit feathers from polluted sites in Belgium (Janssens *et al.,* 2001). The sites can be grouped as either Very High Ni content (Barberspan 2002, Rietvlei 2002 Roodekrans 2002 and 2005) and High Ni content (Barberspan 2005, Rietvlei 2005, Olifantsvlei 2005 and Holfontein 2005). This might show that there is some Ni pollution in the study area of this study.

4.2.10 Lead

The values obtained in this study covered a wide range, the same as the levels of Pb from great Tit feathers along a pollution gradient in Belgium (Janssens *et al.,* 2001), two tit species from Belgium (Eens *et al.,* 1999) and various tits species over a pollution gradient in Poland (Sawicka-Kapusta *et al.,* 1986). They were however a lot lower than those recorded for tit feathers at a polluted site in Belgium (Dauwe *et al.,* 2002). But again all the values were higher than those recorded for Sand Martins in Hungary (Vallner *et al.,* 2000) and American Dippers in Canada (Morrisey *et al.,* 2005). The level of Pb recorded at Roodekrans in 2002 were almost the same as the level of Pb from feathers from Zebra Finches exposed to 25 ppm lead for 30 days in the laboratory (Dauwe *et al.,* 2002). The sites are grouped as high Pb content

(Rietvlei 2002 and Roodekrans 2005), medium Pb content (Barberspan 2005, Rietvlei 2005 and Roodekrans 2002) and low Pb content Barberspan 2002, Olifantsvlei 2002 and Holfontein 2002).

4.2.11 Strontium

There are not a lot of data available on the level of Sr in the feathers of birds. The level of Sr in the feathers of from Sand Martins in Hungary is similar to the middle values obtained from this study (Vallner *et al.,* 2001).

4.2.12 Zinc

Great Tit feathers from even the most polluted site in two Belgian studies were lower than the lowest value obtained in this study (Janssens *et al.,* 2001; Dauwe *et al.,* 2002). The levels of Blue Tit feathers from the reference site in Tenerife in the Canary Islands were in the range of values form this study (Eens *et al.,* 1999). But again the levels from the polluted sites were lower than the lowest value from this study. The values were also higher than those for tits in Poland (Sawicka-Kapusta, *et al.,* 1986) and American Dippers in Canada (Morrissey *et al.,* 2005). The high values from this study are similar though to levels found in Black-billed Magpie feathers from near a zinc smelter in Poland (Dmowski, 1999). All the sites can thus be classified as high Zn content. This suggests that there might be Zn pollution occurring in the study area.

4.3 Conclusion

In general Olifantsvlei 2002 and Holfontein 2002 had the lowest metal content for most metals. Rietvlei 2002 had mostly the highest levels of metal content for most metals. The levels of metals mostly correspond well to levels for passerines from other parts of the world. The levels of Al, Cr, Fe, Ni and Zn were very high when compared to other studies, which suggest that there may be pollution of these metals at the sites. One of the reasons might be the geology of the area, especially at Roodekrans where the site was located at a quarry. Weltevreden Park, which is situated next to Roodekrans, has a high aluminium content in the clay (Geyser, 2002). It is also important to keeping mind that the moulting of the feathers could have had

an influence on the results (Burger, 1993). To prevent this, only breast feathers were used.