FINAL REPORT

AN OVERVIEW OF THE PESTICIDE AND METAL LEVELS PRESENT IN POPULATIONS OF THE LARGER INDIGENOUS FISH SPECIES OF SELECTED SOUTH AFRICAN RIVERS

by

RGM Heath* and M Claassen

Division of Water, Environment and Forestry Technology,
C S I R

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TERMS OF REFERENCE

The aims of the study, as agreed in the original contract between WATERTEK, CSIR and the Water Research Commission were as follows:

1. To integrate information from, and collaborate with, researchers studying the ecological features of five rivers in the Mpumalanga and Northern Provinces that flow through the Kruger National Park (KNP) and one Western Cape river. Existing data and study sites with habitats specific to selected species of fish will be used in order to maximize fishing efforts.

2. To utilize information from completed and presently undertaken catchment studies of the selected rivers, in collaboration with researchers currently working in the field, to determine the point and possible diffuse sources of pesticides and metal pollution. Existing land usage, estimates of the pesticides most commonly used and the specific metal variables associated with the industries in each river catchment will be used to select the specific variables for analysis.

3. To catch selected species of the larger indigenous fish in these rivers, at sites where pesticide and/or metal pollution is expected. Techniques developed by the researcher in charge of this proposal will be used to selected specific species of fish as well as the particular fish tissues in which pesticide and metal levels will be determined.

4. To establish the current body loads of pesticides and metals present in the larger species of indigenous fish in the selected rivers for the period of study.

5. In collaboration with other researchers and the Department of Water Affairs & Forestry, the current fish body loads and monitoring techniques developed in this report will be proposed for the implementation of a National Bioaccumulation River Surveillance Programme for pesticides and metals in South African rivers.

Anticipated benefits

- Factual information on pesticide and metal levels in selected indigenous fish in five rivers that flow through the Kruger National Park and a major Western Cape river.

EXECUTIVE SUMMARY

1. BACKGROUND

There is an increasing public awareness of the environmental importance of water and the importance of not destroying the natural environment when developing water resources. In semi-arid climates it is very important to find a balance between water resource development and maintaining the natural environment (DWAF 1995a). Recently the needs of the environment, particularly the riverine environment, have been increasingly taken into account and the impact of development is beginning to be taken seriously. The National Water Act of 1998 advocates that the environment is the resource base which needs to be protected. Only once this resource reservoir has been protected and sufficient water is allocated to meet it's requirements will the other users be catered for. The environment will no longer be considered as a user of water, competing with other users such as industrial, agriculture, potable, recreational and municipal users.

The rapid international growth of environmental monitoring over the past two decades has come about due to man's interest in pollution being centred on its effects on living organisms. Public pressure to improve the environment, coupled to the declining international water resources quality, has resulted in biological monitoring enjoying even greater interest in recent times. It is now generally understood that measurements of only the physical and chemical attributes of water cannot be used as surrogates for assessing the health of an aquatic system (Karr and Dudley 1981). Chemical monitoring misses many man-induced disturbances, such as flow alterations and habitat degradation, that impair use of the aquatic habitat. Furthermore, the monitoring of water quality variables often does not reflect short-term events that may play a critical role in determining the ecosystem health. It is now widely accepted internationally that biological assessment techniques should be incorporated into water quality management policies in order to adequately protect aquatic resources. The implications of biological monitoring are that the resource should be protected sufficiently to ensure its sustainable and safe use.

Pollution of South African surface waters by pesticides and fertilizers, mainly of agricultural diffuse origin, and by metals, mainly derived from an industrial point source origin, is a cause of increasing public concern. This concern has escalated rapidly in recent years following major fish kills in Mpumalanga and Eastern Cape rivers. Chemicals (pesticides and metals) released into the environment are transported and redistributed among the different compartments in the environment, with transport across membranes into organisms being one of the processes. The impacts of these pollutants on aquatic ecosystems are either dramatic and obvious, due to immediately lethal doses, or insidious due to gradual accumulation of lethal concentrations in the body tissues and organs of otherwise healthy organisms. In the latter case, ecosystems quietly and dramatically change. The insidious bioaccumulation which lies at the root of public concern and fear, forms the core of this research.

Aquatic organisms tend to integrate all the stresses placed on the aquatic system and reflect combined effects over an extended period of time. Aquatic organisms are recognized as bio-accumulators of pesticides and heavy metals and consequently can be used for monitoring of pesticides and heavy metal eutrophication.

Fish are considered to be a suitable component of the aquatic system to monitor because they integrate the effect of detrimental environmental changes as consumers which are relatively high in the aquatic food chain. Fish as indicator organisms for biological monitoring have a high public profile and consequently are used extensively for conservation status and bioaccumulation studies. Furthermore fish are good organisms to use in biomonitoring and specifically bioaccumulation because : -

- they are relatively long-lived and mobile, are good indicators of long-term effects and habitat changes,
- fish communities usually indicate a range of species representing a variety of trophic levels
- fish are high in the aquatic food chain and are eaten by man, making them important subjects for assessing contamination,
- fish are relatively easy to collect and identify to the species level.
  - Environmental requirements of common fish are comparatively well-known
  - Life history information is known for some species
  - Fish distribution information is available
- aquatic life uses (water quality standards) are typically characterized.
- there are 50 species of fish regarded as endangered species in the South African Red Data Book (Skelton 1993).

Fish do, however, have the following shortcomings as indicators of pollution : -

- they are mobile and can move away from pollution
- their mobility means that the if a fish is caught in an area it might not reflect the pollution of that area

- fish are able to regulate certain elements and by so doing the levels in their bodies might no be a true reflection of the surrounding environment.

It is well known that fish accumulate metals in their tissues and organs when they are exposed to metal polluted water. The uptake of metals occurs via the skin and gills whilst the intake via contaminated food and drinking water. After uptake metals are transported in the blood and thus brought in contact with the organs where the metals can bind to proteins and amino acids. The total intake of all metals are not all accumulated as the levels of most metals are regulated by certain biological strategies and excretion of metals occur via a variety of pathways. Bioaccumulation of metals is also influenced by a variety of environmental factors and certain factors related to the organism itself.

Objectives of study

This report focuses on the bioaccumulation of pesticides and metals in indigenous fish species from six South African rivers. The body loads (1989 - 1993) of pesticides and metals in the fish of the selected rivers will be compared with each other and literature values. A protocol will be tested and, if suitable, can be used to monitor South African rivers for pesticide and metal bioaccumulation levels in fish tissue.

2. METHODOLOGY AND CATCHMENT CHARACTERISTICS

The sampling for this study sites were depend on the understanding of whole catchments and the locations where diffuse and point sources of pollution were expected. The expected variables of concern were analyzed in samples of river water and fish tissue. This research plan integrated information from, and collaborate with, existing catchment studies and research projects being undertaken on five rivers which flow through the Kruger National Park and one Western Cape river. The Mpumalanga and Northern Province rivers that will be studied are: the Letaba River (mainly intensive agriculture along its banks with some industrial pollution, as well as being seriously affected by water abstraction in winter); the Sabie River (agriculture and a limited number of industries); the Luvuvhu River (subsistence agriculture and erratic seasonal flows); the Crocodile River (most intensive irrigation system in South Africa with numerous point and diffuse sources of domestic and industrial pollution) and the Olifants River (intensive and subsistence agriculture and numerous point and diffuse sources of industrial pollution). The Western Cape river chosen viz. the Berg, is a river with intensive agriculture, aquaculture and industry (**Tables 1 and 2**).

During each sampling trip water quality, fish biology and tissues of fish caught were collected for metal and pesticide analysis. Specific species of fish as well as specific tissues were evaluated for use in the biomonitoring of eutrophied rivers in South Africa. The actual water quality and expected pesticides (using actual 1991 usage) in the rivers due to runoff were compared to the findings in the fish tissues. The resultant pesticide values in the fish tissue were used to determine possible human health assessment if the fish were consumed at differing amounts.

Table 1: Characteristics of the catchments of the study rivers.

Characteristics	**Crocodile**	**Letaba**	**Sabie**	**Luvuvhu**	**Olifants**	**Berg**
Catchment area (km^2)	10 440	13 200	6 437	3 568	54 500	9 000
Irrigated area (ha)	95 000	34 000	11 300	9 000	103 000	7 500
Afforested area (ha)	172 200	47 520	71 100	14 600	72 000	7 500
Dry land agriculture (ha)	290 000	16 000	11 570	subsistence	1.2×10^6	3 267
Mean annual rainfall (mm/a)	879 summer	671 summer	833 summer	731 summer	675 summer	524 winter
Runoff (Mm^3/km^2)	118514 seasonal	59964 seasonal	134314 perennial	89072 seasonal	47475 seasonal	116286 perennial
People/km^2	45.9	92.9	134.8	84.9	84.6	37.4
Industries						
Pulp & paper	✓					
Fruit processing	✓	✓				✓
Saw mill	✓	✓	✓			
Sugar refinery	✓					
Metal refinery	✓				✓	
Winery						✓
Power generation					✓	
Tannery and leather						✓
Small industries	✓	✓	✓	✓	✓	✓
Mining	✓		✓	✓	✓	

Where ✓ = activity occurs in catchment

Table 2: **Major crops (✓) grown in the catchments studied.**

Crop	Crocodile	Letaba	Sabie	Luvuvhu	Olifants	Berg
Sugar cane	✓		✓			
Bananas	✓	✓	✓	✓	✓	
Citrus	✓	✓	✓		✓	
Mangoes		✓		✓		
Tomatoes	✓	✓			✓	
Vegetables	✓	✓	✓	✓	✓	
Maize	✓			✓	✓	
Avocados			✓			
Tobacco	✓			✓	✓	
Paw Paws	✓	✓	✓	✓	✓	
Wheat						✓
Grapes						✓

3. RESULTS

3.1 Water quality

The Olifants River shows a very high mean conductivity values in access of 100 mS/m. These high conductivity values are related to land usage disturbances such as mining, agricultural runoff and rural settlement activities in the catchment. The catchment with the lowest conductivity values was the Sabie (9 to 15 mS/m).

The nutrient values in the Olifants and Luvuvhu Rivers indicate high mean values. In the Olifants River these relatively high values are due to fertilizers used in agriculture and the mining activities around Phalaborwa. In the Luvuvhu River catchment the nutrients loads originate from agriculture runoff and sewage effluent that is returned to the river in a treated or untreated form. The mean sulphate value for the Olifants River is four times that of the other rivers sampled. These high values originate from the mining activities that occur in the upper and lower catchment.

Results from surveys done to establish potential metals of concern in the catchments studied in this report are shown in **Table 3.** The mean values for iron in the river sampled indicate minor variations between rivers. The Crocodile River, however, yielded a slightly higher mean value due to evident outliers. Values for lead were below the limits of detection for all samples taken. Nickel values recorded in the rivers were lower than the limits of detection for all rivers except the Luvuvhu River where a mean of 20 μg/ℓ was recorded. Mean values for zinc indicate relatively high values for the Crocodile River only, with a mean of 500 μg/ℓ and outliers in excess of 5000 μg/ℓ.

Table 3: **Origins of possible metal contamination to the water quality of each of the catchments** (Chunnet *et al.* 1990, CSIR 1991, SRK 1991, Bath 1992, Claassen 1996, DWAF 1995b+c).

Probable Metal Origin	**Possible source of metals in each catchment**					
	Berg	**Crocodile**	**Letaba**	**Levuvuhu**	**Olifants**	**Sabie**
Geological	Fe,Zn, Al, Mn	Fe, Al, Mn, Cr, Zn, As	Sb, Cu, Zn, Fe, Mn	Fe, Cu, Mn, Cr	Fe, Al, Ni, Cr, Cd, Sr, Zn, Pb, Sb, Hg, Cu, Mn, V	Cr, Fe, Mn, Al
Agricultural	Zn, Cu, B	Zn, Cu, B	Zn, Cu, B	Zn	Fe, Al, Zn	Zn, B
Tanning and leather finishing	Cr					
Pulp and paper		Al, B, Cr, Co, Cu, Hg, Pb, Mn, Ni, Zn				
Metal Refineries		Mn, Fe, Al, Mn, B			Fe, Al, Cu, Mn	
Mining*		Fe, Al, As, Zn, Cu, Mn	Cr, Zn, Sb, Fe, Mn	Cu, Fe, Zn	Cu, Sr, Mn, Zn	Fe, Al, As, Mn

* Includes leaching from waste rock and low-grade ore stockpiles, as well as direct mine water and effluent discharge.

The highest aluminium levels detected were in the Klipspruit River 100 m above the confluence with the Olifants River. These high aluminium levels detected were 1.9 mg/ℓ which is considerably higher than the levels recorded in the other rivers. The highest arsenic value (15 μg/ℓ) were recorded at the Kaapmuiden site of the Crocodile River. Apart from two sites (30 μg/ℓ) in the Olifants River the levels of cobalt were below the levels of detection in the rivers monitored. Apart from the Sabie River (6 μg/ℓ) the cadmium levels recorded were below the levels of detection. The chromium values monitored were all below the levels of detection. Low levels of copper were found only in the Letaba, Luvuvhu and Olifants Rivers. Only the Meetwal in the Olifants River had a high level of copper (0.12 mg/ℓ). The manganese levels detected in the Crocodile River were generally higher than the other rivers. The Hengel (Fishing) Club had consistently higher values with a maximum manganese value of 1.2 mg/ℓ. The mercury levels recorded were generally lower than the levels of detection with traces being recorded in the Crocodile River (8 μg/ℓ maximum).

3.2 Fish biology

Sixteen species of fish were used for tissues analysis for either pesticide or metal determination (Table 4). Four of these species caught and analyzed are exotic species viz. common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*) largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*). As species were abundant in the catchments surveyed tissues were collected and analyzed from representative specimens.

The stomach content analysis of the fish for the Crocodile and Letaba Rivers are indicated that there were dietary difference between the rivers for some of the fish species especially for *C. gariepinus*, *O. mossambicus* and *S. intermedius*. The *C. gariepinus* in the Crocodile River were mainly eating plant and detritus whilst the same species in the Letaba River were more omnivorous. The *O. mossambicus* in the Letaba River were eating a wider variety of algal material when compared to the same species in the Crocodile River. The *S. intermedius* in the Letaba River were eating a large percentage of fish which made up less than one percent in the diets of the same species in the Crocodile River.

Table 4: **Common and scientific names of the species of fish from which tissues were taken in the Letaba, Olifants, Sabie, Luvuvhu, Crocodile and Berg Rivers in (1989 - 1993, * = exotic species).**

Common Name	Species	Abbreviation
Large-scale Yellowfish	*Barbus marequensis*	*B mar*
Spotted-tailed Robber	*Brycinus imberi*	*B imb*
Sharptooth Catfish	*Clarias gariepinus*	*C gar*
Common Carp	*Cyprinus carpio**	*C car*
Tigerfish	*Hydrocynus vittatus*	*H vit*
Silver Carp	*Hypophthalmichthys molitrix**	*H mol*
Purple Mudsucker	*Labeo congoro*	*L con*
Plumbeous Labeo	*Labeo molybdinus*	*L mol*
Red-nosed Labeo	*Labeo rosae*	*L ros*
Silver Labeo	*Labeo ruddi*	*L rud*
Largemouth Bass	*Micropterus salmoides**	*M sal*
Smallmouth Bass	*Micropterus dolomieu**	*M dol*
Mozambique Tilapia	*Oreochromis mossambicus*	*O mos*
Butter Catfish	*Shilbe intermedius*	*S int*
Brown Squeaker	*Synodontis zambezensis*	*S zam*
Southern Redbreasted Tilapia	*Tilapia rendalli*	*T ren*

3.3 Metals in fish

Metals per tissue

The tissues of all the fish studied indicated that there was a marked difference between tissues with respect to metal residue levels (**Table 5**).

From the analysis above it indicates that the following tissues have consistently higher metals in the species of fish analyses irrespective of river:

Liver :- Fe, Cu, As, Cd, Co, Mg, Ni, Cd, Hg
Gills :- Zn, Al, Mn
Testes :- Al, Cr

Metals per species

Table 5: **The highest mean metal loads per tissue.** (Tissues with less than three metal determinations were not included).

Metal	Tissues			
	Liver	Gills	Ovaries	Testes
Al	x	xx		xxx
As	xxx	xx		
Cd	xxx	xx	x	
Cr	xx	x		xxx
Co	xxx		x	xx
Cu	xxx	xx		x
Fe	xxx	xx		x
Pb	xxx	xx		
Mg	xxx			
Mn	x	xxx		xx
Ni	x	xxx		xx
Zn	x	xxx	xx	

Where : xxx = highest means, xx = second highest means, x = third highest means.

The following is a synthesis of the species of fish with the highest mean metal body loads:-

Al : *L. rosae* > *L. congoro* > *C. gariepinus*, range 5 to 69782 µg/g.

As : *O. mossambicus* > *B. marequensis* > *C. gariepinus*. range 0.3 to 6.5 µg/g.

Cd : *L. congoro* > *L. rosae* > *C. carpio*, range (0.02 to 10.9.

Co : *L. rosae* > *C. gariepinus* > *O. mossambicus*. range 0.1 to 49.5 µg/g.

Cr : *L. rosae* > *O. mossambicus* > *L. congoro*, range 0.03 to 70.4.

Cu : *L. ruddi* > *L. rosae* > *L. congoro*. range 0.3 to 6 802 µg/g.

Fe : *H. vittatus* > *C. gariepinus* > *O. mossambicus*. range 0.03 to 37 900 µg/g.

Mn : *C. carpio* > *L. rosae* > *L. ruddi*, range 0.4 to 680 µg/g.

Pb : *L. rosae* > *O. mossambicus* > *C. gariepinus*. range 0.4 to 879 µg/g.

Ni : *O. mossambicus* > *T. rendalli* > *B. marequensis*. range 0.09 to 41.7 µg/g.

Zn : *C. carpio* > *L. rosae* > *L. congoro*. range 1 to 776 µg/g.

The species of fish with the highest metal levels were:

L. rosae > *O. mossambicus* > *C. carpio* > *C. gariepinus* > *L. ruddi* > *L. congoro*.

River metal values

The mean metal values detected in the combined fish tissues per river indicate the following order of metal loads per river sampled:

Al	:	Letaba > Olifants > Crocodile > Berg > Sabie.
As	:	Berg > Crocodile.
Cd	:	Olifants > Sabie > Crocodile > Letaba > Berg.
Cr	:	Letaba > Crocodile > Olifants.
Co	:	Letaba > Olifants > Crocodile.
Cu	:	Olifants > Letaba > Luvuvhu > Crocodile > Berg.
Fe	:	Letaba > Luvuvhu > Olifants > Sabie > Crocodile.
Pb	:	Olifants > Letaba > Crocodile > Berg.
Mn	:	Luvuvhu > Berg > Olifants > Letaba > Crocodile > Sabie.
Ni	:	Crocodile > Letaba.
Zn	:	Luvuvhu > Olifants > Berg > Sabie > Letaba > Crocodile.

The metal results of the fish at selected river sites indicate that arsenic, copper, iron, manganese and zinc levels in fish tissues corresponded to known environmental levels of contamination and consequently fish tissues can be used to detect pollution of these metals.

3.4 Pesticide levels in fish

Fish pesticide tissue values

The pesticide levels in the tissues of all the fish studied indicated that there was a marked difference between tissues with respect to pesticide residue levels (**Table 6**).

From the results in this study the following tissues have consistently higher pesticides in the species of fish analysed, irrespective of river:

fatty tissues (fat, testes, ovaries), and liver.

Table 6: A ranking of the highest pesticide concentrations in the fish tissues.

Pesticides	Tissues					
	Ovaries	Fat	Testes	Liver	Flesh	Gut
BHC		xx	xxx	x		
Lindane		xx	x			xxx
Dieldrin		x		xxx	xx	
DDE		xxx		x		xx
DDD		xxx	x			xx
DDT	x	xxx				xx
Diazianon		xx	x		xxx	
Endosulfan		x		xx		xxx
Mercapthion	x			xx	xxx	
Pirimos		xxx		xx		
Aldrin						xxx
Atrazine		xxx	xx	xx		

Where: xxx = highest mean value detected, xx = second highest mean value detected, x = third highest mean value detected.

Pesticides per species

Table 7 is a synthesis of the species of fish studied with the highest pesticide body loads.

These six species of fish with the highest pesticide loads were:
L. molybdinus > *C. gariepinus* > *H. vittatus* > *L. rosae* > *O. mossambicus* > *B. marequensis*

Pesticides per river

The mean pesticide values detected in the lumped fish tissues per river indicate the following order of pesticide loads per river:

BHC : Crocodile > Letaba > Olifants > Sabie > Luvuvhu and Berg.
Dieldrin: Crocodile > Letaba > Olifants > Berg > Sabie > Luvuvhu.
Lindane: Crocodile > Letaba. with traces amounts in the other rivers.
DDD: Letaba > Luvuvhu > Sabie > Olifants > Crocodile > Berg.
DDE : Letaba > Luvuvhu > Olifants > Sabie > Crocodile > Berg (0.0473 μg/g) **(Figure 1)**.

Table 7: **The highest mean pesticide values recorded per species of fish (all rivers combined, refer to Table 4 for abbreviations).**

	Species									
Pesticides	***O mos***	***C car***	***L mol***	***B mar***	***S int***	***H vit***	***C gar***	***L ros***	***T ren***	***L con***
BHC				xx		x	x			xxx
Lindane			xxx			xx	x			
Dieldrin	xx					xxx				x
DDE						x	xx	xxx		
DDD						xx	xxx	x		
DDT	x					xxx	xx			
Diazianon			xx	x					xxx	
Endosulfan			xxx	xx			xx			
Mercapthi on			xx				x		xxx	
Pirimos	x		xx						xxx	
Aldrin	xxx									
Heptachlor			xx					xxx		
Atrazine	xx	xxx								

Where: xxx = highest mean value detected, xx = second highest mean value detected, x = third highest mean value detected.

DDT : Letaba > Olifants > Luvuvhu > Crocodile > Sabie > Berg.

Heptachlor: Crocodile River > traces in the other rivers.

Endosulfan: Crocodile River > traces in the other rivers.

Mercapthion: Crocodile River > traces in the other rivers.

Diazinion: Crocodile River > traces in the other rivers.

Pirimiphos: Crocodile River > traces in the other rivers.

Aldrin : Crocodile River > traces in the other rivers.

Endrin : Traces detected in all rivers.

Atrazine: Berg River, traces in other rivers only.

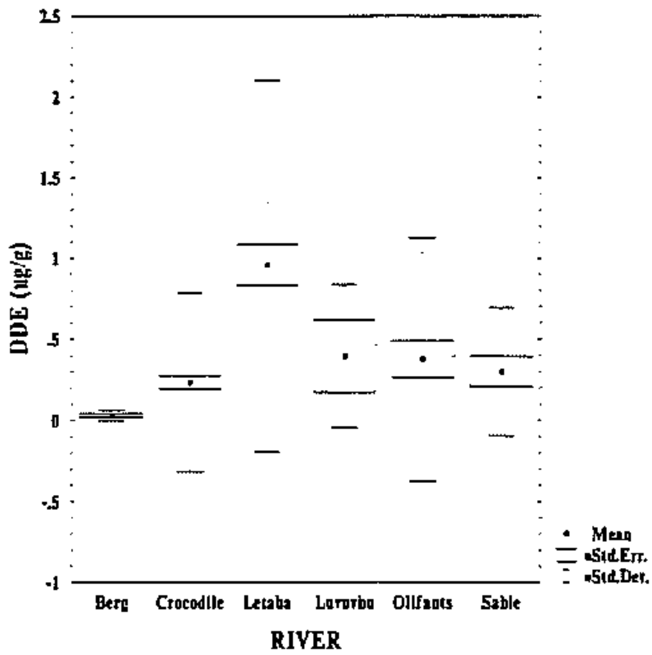

Figure 1: DDE levels in the fish tissues per river.

4. DISCUSSION OF TRENDS

4.1 Metals in fish tissues

In South Africa metal bioaccumulation in fish was first undertaken by Greichus *et al.* (1977) in the Voelvlei and Hartbeespoort Dams. In recent years there has been a dramatic increase in the fish metal bioaccumulation literature that has been generated in South Africa. Rivers that have been studied include the Olifants (Mpumulanga. Coetzee 1996. Du Preez and Steyn 1992. Grobler *et al.* 1994. Seymore 1994. Seymore *et al.* 1994. Kotze 1997). Crocodile (Roux *et al.* 1994). Sabie. Luvuvhu. Letaba. Berg. Vaal (Adendorff and van Vuren 1996) and Jukskei (IWQS 1994) and dams (Loskop, Middleburg - Barnhoorn 1996. Germiston - Bezuidenhout *et al.* 1990. De Wet *et al.* 1994. Schoonbee *et al.* 1996. Kotze 1997 and Krugerdrift - van den Heever and Fry 1994. 1996a and 1996b).

A variety of different water bodies ranging from gold mine polluted dams (Bezuidenhout *et al.* 1990 and De Wet *et al.* 1994. Schoonbee *et al.* 1996), sewage effected dams (van der Heever and Fry 1994, 1996a & 1996b). the middle Vaal (Adendorff and van Vuren 1996). an urban runoff polluted river (IWQS 1994) and various rivers that enters the Kruger National Park (Olifants and Crocodile) after passing through various land usages such as mines and intensive agriculture (Du Preez and Steyn 1992, Seymore 1994, Roux *et al.* 1994, Grobler *et al.* 1994, Coetzee 1996, Claassen 1996, Du Preez *et al.* 1997, Kotze 1997, Robinson and Avenant-Oldewagen 1997). These South African studies have also been undertaken on several species of fish and tissues (**Table 8**). These mean metal values per tissue were converted to a common unit ($\mu g/g$ dry weight), in order to compare results, using mean tissue moisture contents. The species and rivers were combined. Some 1400 fish have been used in these studies over the past six years.

Intestine : - could be fore-, mid- or hind gut, with or without fatty tissue associated with the intestine. Intestine will also include food in various degrees of decay. In detrivores the intestine contents will be mainly sediment which could have high metal loads. As the majority of this sediment is released in the faeces the metal values associated with intestine need to be treated with circumspect as there is no clear indication that these metals will stay in the fish (be accumulated) or be excreted as faeces. Also attached to intestine could be intestinal fat which can further complicate issues if this is not removed before analysis is undertaken.

The present lack of a bioaccumulation protocol makes interpretation of these tissue results difficult for the following reasons : -

Gills : this could be the whole gill or with or without - lamellae, filaments or rakers. Depending on the turbidity of the river the metals found associated with the gills could only be attached to the gill surface and might not be accumulated in the fish tissues. If the gills were thoroughly washed with distilled water before analysis is undertaken for metal then a different metal accumulation pattern could emerge. The extensive vascular network and large surface area of the gills does, however, make them a suitable organ for metal uptake.

Skin : this could mean muscle, flesh with or without scales or all of these. If fish muscle is used (as it was used in this study) then it is abundant on the fish and can be used to determine the human health risk if the fish are eaten.

Gonads : this could mean testes or ovaries. Normally associated with these tissues is abdominal fat which would need to be removed before analysis is undertaken. The gonads metal loads are highly variable and are also seasonally dependant. In the non-breeding season the mass of gonads available are limiting for use in biomonitoring studies.

The choice of a specific fish tissue for metal bioaccumulation will be dependant on the specific requirements of the monitoring programme.

Table 8: **The mean metal concentrations per fish tissue (all species of fish and rivers combined,** Adendorff and van Vuren 1996, Barnhoorn 1996, Bezuidenhout *et al.* 1990, Claassen 1996, Coetzee 1996, De Wet *et al.* 1994, Du Preez and Steyn 1992, Du Preez *et al.* 1997, Grobler 1994, Grobler *et al.* 1996, Kotze 1997, IWQS 1994, Robinson and Avenant-Oldewagen 1997, Roux *et al.* 1994, Seymore *et al.* 1994, Schoonbee *et al.* 1996, van den Heeven and Fry 1994, 1996a and 1996b). **The shaded areas indicate the tissue with the highest metal load.**

Tissue	Mean metal loads (µg/g dry weight)								
	Zn	Cu	Fe	Mn	Al	Ni	Pb	Cr	Cd
Liver	403	179	1434	25	83	36	19	25	9
Fat	40	8	162	5	30	10	16	4	5
Muscle	110	7	156	9	77	31	15	23	6
Gill	663	14	506	76	167	50	21	48	3
Skin	685	26	529	21	52	40	42	39	
Spleen	211	32	1090	8		256	39		
Vertebrae	498	8	243	30		102	29	42	
Intestine	105	29	582	454		58	30	110	7
Gonads	917	10	294	12	259	35	22	32	3
Bile	6	7	60	2		6	8	7	
Brain	335	100							
Heart	196	42							
Kidney	88	17	230	3		4	8	5	

Metal bioaccumulation studies using fish in South African rivers could use the following tissues:-	
Liver :	**zinc, copper, iron, cadmium**. Liver is a de-toxicant organ and has high loads of these metals. Most fish livers are easy to dissect as a single organ and are large enough to supply sufficient tissue for metal determination.
Gills :	**manganese** and **zinc**. Gills are easy to dissect and have direct contact to any pollutants in the water body.
Vertebrae :	**strontium** and **zinc**. Could be used to determine long term exposure.
Muscle :	**lead**. Should be used to determine the human health risks if this fish tissue is consumed.

4.2 Pesticide residues in fish tissues

Several studies have been undertaken in South Africa on pesticide residues in fish. These studies range from marine and estuarine (de Kok 1985, Sibbald *et al.* 1986), to inland lakes (Greichus *et al.* 1977) and rivers (Piek *et al.* 1981, Bouwman *et al.*1990, Grobler 1994, Roux *et al.* 1994, Claassen 1996). In order to compare these value the literature values were converted to μg/kg on a wet weight basis (Table 9). Meaningful comparisons of this data are complicated due to the vast variability of methods and tissues used in these studies. For example the tissues used for these determinations were not standardised. The array of tissues varied from whole fish, fish without heads and scales, fillets and muscle and Greichus *et al.* 1977 does not state what tissues were used. To further complicate comparisons are the way that the results are expressed as some are expressed in terms of a basis of fat whilst others are not.

For pesticide bioaccumulation studies using fish in South African river the following tissues are recommended:-	
Intestinal fat:	**DDT, DDD, DDE, Lindane, Endosulfan, Atrazine, Aldrin, Pirimiphos,**
Testes:	**BHC**
Liver:	**Dieldrin**
Muscle:	**suitability of fish for human consumption**

The present lack of a bioaccumulation protocol makes interpretation of these tissue results difficult for the following reasons : -

Gut : as a tissue is not reliable for pesticide residue analysis in fish as the guts with the highest pesticide residue values were found in *L. rosae* in the Letaba River. These "gut" samples were the intestines of the fish which were surrounded by intestinal fat and consequently the high pesticide loads determined are associated with the fatty tissue.

Flesh, skin or muscle : if the actual area where this tissue is collected from the fish and the actual method is specified (dorsal muscle below the start of the dorsal fin, scales removed and skin kept) then this tissue is realistic for pesticide residue analysis as it has an important role in the acceptability of the fish muscle for human consumption.

The following species of fish had the highest pesticide loads in the rivers studied:

Labeo species:	BHC, Lindane, DDE, Heptachlor, Endosulfan
C. gariepinus:	DDD
T. rendalli:	Mercapthion, Diazinon, Pirimiphos
O. mossambicus:	Aldrin
C. carpio:	Atrazine

The review of the limited pesticide studies undertaken on fish in South Africa indicates that due to the lack of standardization of analytical methods (whole fish, decapitated, muscle only etc.) a wide variety of species of fish have indicated high pesticide residues. These species vary from algae eaters (*O.mossambicus*), detritivores (*Labeo* sp.), omnivores (*S. intermedius, C. gariepinus*) and piscivorus (*H.vittatus*).

Table 9 : Literature levels of pesticides recorded in fish in southern Africa (converted to µg/kg wet weight).

Study	DDT	DDD	DDE	Endosulfan	Dieldrin	BHC
Crocodile (Hartbeespoort Dam) Greichus *et al.* (1977) whole fish	*O. mossambicus* 900 *C. flaviventris* 1200	*O. mossambicus* 1900 *C. flaviventris* 1300	*O. mossambicus* 900 *C. flaviventris* 1400		*O. mossambicus* 1200 *C. flaviventris* 1300	
Berg (Voelvlei Dam) Greichus *et al.* (1977) whole fish	*M. salmoides* 500 *L. macrochirus* 600	*M. salmoides* 500 *L. macrochirus* 100	*M. salmoides* 4200 *L. macrochirus* 600		*M. salmoides* 500 *L. macrochirus* 300	
Berg (Voelvlei Dam) Claassen (1996) Various tissues	*O. mossambicus* 7 *C.carpio 10* *M. dolomieus 5*	*O. mossambicus 47* *C.carpio 31* *M. dolomieus 150*	*O. mossambicus* 72 *C.carpio 39* *M. dolomieus* 20	*O. mossambicus* 5 *C.carpio 5* *M. dolomieus 5*	*O. mossambicus 5* *C.carpio 5* *M. dolomieus 5*	*O. mossambicus < 1* *C.carpio < 1* *M. dolomieus < 1*
Limpopo (Olifants, Letaba, Crocodile) Pick *et al.* (1981) on a basis of fat (muscle, liver, skin) mg/kg	*O. mossambicus* 565 *C. gariepinus* 152 *Labeo sp.* 43		*O. mossambicus* 1863 *C. gariepinus* 2880 *Labeo sp.* 379 *Barbus sp.* 918	*O. mossambicus* 50 *C. gariepinus* 124 *Barbus sp.* 588	*O. mossambicus* 144 *C. gariepinus* 133 *Labeo sp.* 51	*O. mossambicus* 37 *C. gariepinus* 38 *Labeo sp.* 19 *Barbus sp.* 26
Pongolo Bouwman *et al.* (1990) fillets	*H. vittatus* 15 sd 17 *O. mossambicus* 7 sd 17 *E. depressirostus* 5 sd 7	*H. vittatus* 25 sd 33 *O. mossambicus* 17 sd 31 *E. depressirostus* 9 sd 15	*H. vittatus* 54 sd 67 *O. mossambicus* 12 sd 17 *E. depressirostus* 13 sd 21			
Olifants Grobler (1994) head & fins removed	*C. gariepinus* (1.7 - 2.2) *O. mossambicus* 2.2 *E. depressirostus* 27.9 (2.9 - 72)	*C. gariepinus* (2.5 - 3.7) *O. mossambicus* 1.9 *E. depressirostus* 3.9 (1.0 - 13.2)	*C. gariepinus* 8.0 (2.5 - 26) *O. mossambicus* 5.6 (3.1 - 8.4) *E. depressirostus* 94 (22 - 198)			
Crocodile Roux *et al.*, (1994) muscle			*C. gariepinus* 58.5 *O. mossambicus* 14.9 *C. carpio* 3.9 *B. marequensis* 118.9			
Lowveld Rivers This study All tissues - maximum values	Let, *C. gariepinus 1340* Oli,*C. gariepinus 304* Luv,*H. vittatus 238* Sab, *L. ruddi 120*	Let, *C. gariepinus* 1730 Oli,*C. gariepinus* 283 Luv,*C. gariepinus 1009* Sab *H. vittatus 640*	Let, *L. rosae* 955 Oli,*C. gariepinus 361* Luv,*H. vittatus 516* Sab, *L. congoro 298*		Let, *L. rosae* 197 Oli, *L. congoro* 74	Let, *L. rosae* 7 Oli, *L. congoro 8*

Where: Let = Letaba River, Oli = Olifants River, Sab = Sabie River, Luv = Luvuvhu River.

4.3 Human health risk assessment

The standards established to protect aquatic life in Canada and the United States of America (Water Quality Branch. Environment Canada 1979; National Academy of Science - National Academy of Engineering 1972) recommend that residues in fish muscle (wet weight basis) should not exceed 1.0 mg.kg for t-DDT and 0.5 mg.kg for Dieldrin.

Table 10: Summary of pesticide human risk assessment if fish are eaten from selected South African Rivers.

Exposure	Dieldrin	Lindane	Atrazine	DDT	DDE	Endosulfan
Weekly 50g	▲	▲			▲	
Daily 50g	● ▲ ◆	● ▲			▲	◆
Weekly 150g	● ▲	● ▲			▲	◆
Daily 150g	● ▲ ◆	● ▲ ◆			▲	◆

Where: ▲ = maximum value cancer risk, ◆ = maximum value hazard quotient (non-cancer effects), ● = geometric mean cancer risk

Risk higher than those recommended by the US_EPA were detected for dieldrin, lindane and DDE (**Table 10**) when the maximum level of pesticides detected in the fish tissues was used. Hazard quotients, referring to the non-cancer toxicity, were also higher than the recommended US-EPA value of 1 for Dieldrin, Lindane and Endosulfan.

From the results in the present study there are associated human health risks to eating the fish. These risks are however in the worst case scenarios (highest daily weight of fish eaten daily all year round) and are specifically associated with the fish in the Letaba, Luvuvhu and Crocodile Rivers. If the fish were gutted (i.e. remove fat, liver, testes and ovaries) then the fish would be safe for human consumption (Bouwman *et al.* 1990). This is not always the case as the muscles tissue can be associated with high pesticide loads and the resultant high risk potential as in seen in the present study.

4.4 Pesticide usage compared to fish tissue residues

Mean pesticide body loads per species of fish combined were compared to actual pesticide loads used in each catchment. **Table 11** compares the fish tissues that bioaccumulated pesticides with the actual pesticide usage in the catchments studied.

Table 11: **Comparison of actual pesticide usage for the catchments and the bioaccumulation in the fish tissues.**

Pesticides	Berg	Crocodile	Letaba	Luvuvhu	Olifants	Sabie
Lindane	-	+	+	-	-	+
Endosulfan	-	+	-	?	-	-
Mercapthion	+	+	-	+	+	+
Pirimosphos	?	+	+	+	+	+
Aldicarb	+	-	+	+	+	+
Atrazine	+	-	-	-	-	-
DDT etc.						

Where:- - = no bioaccumulation, + = accumulation, ? = usage unknown

The general trend is that pesticides do bioaccumulate in the fish tissues according to the actual pesticide usage in the catchments. Atrazine loads in the fish of the Berg River closely resemble the expected values according to the usage of this pesticide in the catchment. The lack of significant atrazine levels in the tissues of the fish in the other rivers studied indicates that this pesticide is not well accumulated in the tissues or if it is it does not remain in the fish tissues for long periods of time. Lindane residues in the fish from all the rivers studied were similar with the exception of the Letaba and Crocodile Rivers. The Letaba, Luvuvhu and Olifants Rivers indicated biomagnification possible from past rather than present lindane usage in these catchments. Only the fish pesticide residues in the Crocodile River indicated accumulation that resembled the actual usage of lindane, Endosulfan, Mercapthion and Pirimiphos in the catchment. Mercapthion residues in the Crocodile River were slightly higher than in the other rivers which agrees with the actual pesticide usage in the catchment.

5. PROPOSED BIOACCUMULATION MONITORING PROGRAMME PROTOCOL FOR PESTICIDE AND METAL CONCENTRATIONS IN SOUTH AFRICAN RIVERS.

Bioaccumulation must be seen as an additional tool in the toolbox of Ecosystem Health determination. This tool will be used to refine problems as one of the River Health indices of the River Health Programme of DWAF. The overall approach that should be used when planning for the successful implementation of a fish bioaccumulation assessment as outlined in **Figure 2** .This proposed protocol has taken into account the findings of this study as well as numerous interactions with Professors du Preez and Schoonbee's students at Rand Afrikaans University (Barnhoorn 1996, Bezuidenhout *et al.* 1990, Claassen 1996, Coetzee 1996, Seymore 1994, Schoonbee *et al.* 1996, Kotze 1997).

5.1 Appropriate level of assessment

A three levels approach is suggested (**Table 12**).

Level 1: National Rivers Health Assessment - To determine the national status of water bodies and to identify those sites that are harvested (commercially, recreational and subsistence fishing) by humans where edible portions of fish exceed human consumption levels.

Level 2: Human Health Risk Assessment - Conduct intensive follow-ups to determine the magnitude of contamination in edible portions of fish species consumed by humans in water bodies identified in level 1 screening.

Level 3: Impact Assessments or case specific - Conduct intensive sampling at specific sites that are identified by permit applications, by levels 1 and 2, impact assessments etc. to determine the geographical extent of contamination in various sizes and tissues of fish species.

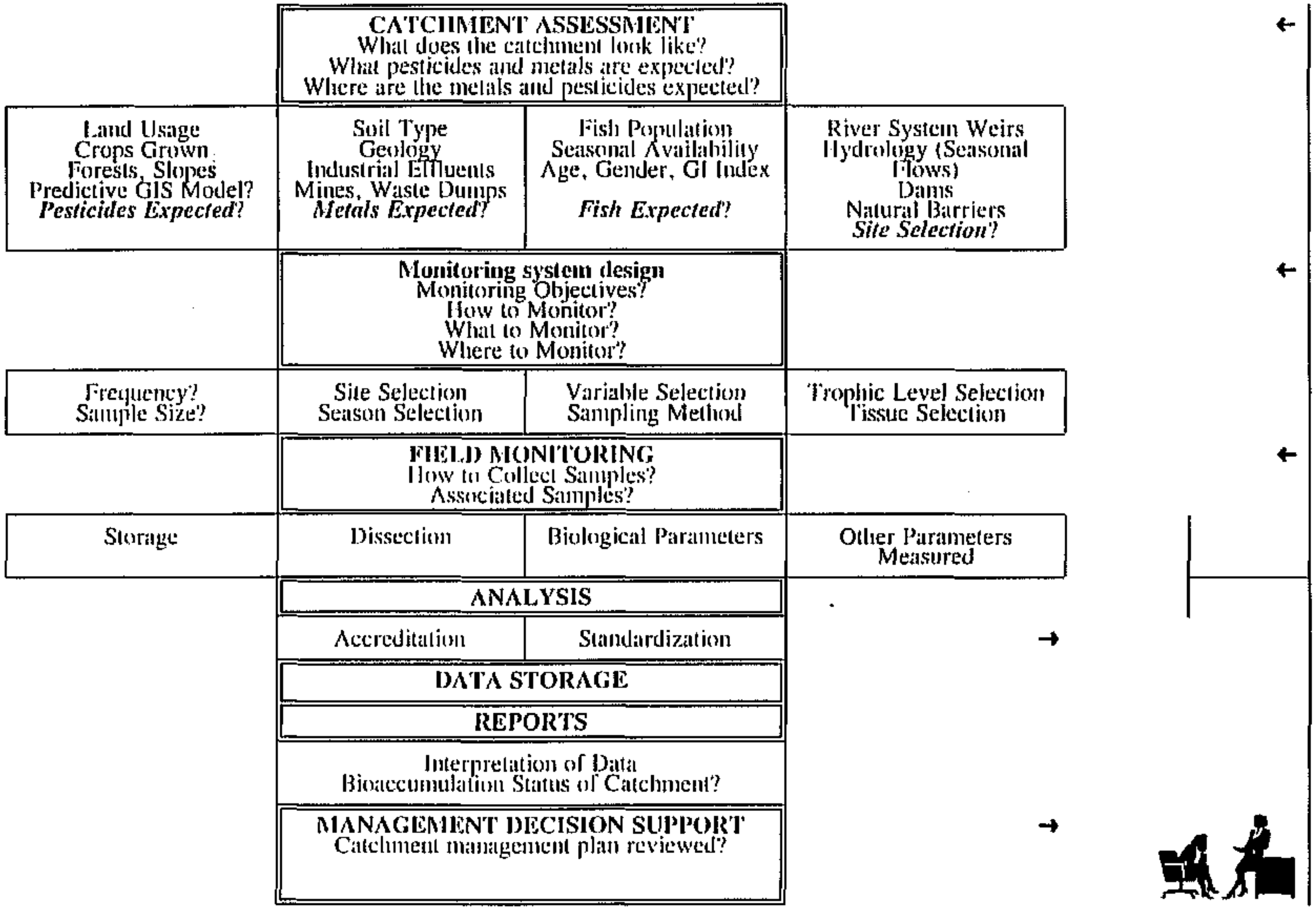

Figure 2: **Proposed bioaccumulation protocol**

Table 12: Proposed levels of assessment for which fish bioaccumulation can be used.

	National Rivers Health Assessment		Human Health Risk Assessment		Impact Assessment	
Resolution scale	National - catchments		National- subcatchments - reservoirs		Localised - rivers reaches	
Sites	200 National biomonitoring		Recreational and subsistence protein resources		Impact focussed	
Frequency of sampling	5 yearly		3 to 5 years		Needs based (days to seasons)	
Seasons	Either before or after rainy season		Before and after rainy season		Needs based (days to seasons)	
Purpose	Baseline of status of fish body loads		Human health risk assessment of eating fish		Determine potential impacts of effluents	
	Pesticides	**Metals**	**Pesticides**	**Metals**	**Pesticides**	**Metals**
Fish trophic level	Omnivore	Detritivore - Omnivore	Eaten or utilised species		Most abundant indicator of specific pollution	
Tissues	Fat - gonads	Vertebrae - flesh	Flesh - fat	Flesh	Fat - gonads	Liver - gills
No. of samples	5	5	5	5	> 10	> 10
Sampling method	Gill or seine nets or shocker				Seine or gill nets, or cages	
Variable selection	Organochlorines, triazines	Fe, Mn, Zn, Co, Cu, Al, Mg	Organochlorines, triazines	Hg, As, Cu, Pg, Cr	Impact dependant	
Linkages	National Rivers Health Programme Catchment Situation Assessments		Human Health Risk Assessment databases Department of Health		Waste Load Allocation Impact Assessment Risk Assessment Chemical Speciation Catchment Management Whole Effluent Toxicity Biomarkers	

This bioaccumulation protocol will have close linkages to the following databases or biomonitoring studies:

- Catchment or situation assessments (land usage, diffuse and point sources of pollution)
- Water quality
- SASS4, HAM, RVI, HQI
- Fish biology, IBI, deformities, parasites, blood haematology, population dynamics, length/mass ratios, liver somatic index, fecundity, recruitment, etc.
- WET (Whole Effluent Toxicity) and ecotoxicology
- Sediments as a reserve of metals and pesticide or as a biotransformer

Bioaccumulation can be used on different scales of impact ranging from rapid (days) or acute, to months (semi-acute), or years (chronic).

National Rivers Health Assessment (Level 1)

This national programme should include this bioaccumulation especially the IBI and use the same sites. This programme will supply baseline data which can be used to compare catchments and be used in management to further determine how well the catchment is being managed.

If a hotspot river or catchment is detected through this programme then the next levels (2 or 3) of bioaccumulation can be activated namely Health Risk Assessment or Impact Assessment.

The frequency of this assessment programme is suggested as every 5 years. The sampling season and method as well as the rest of the suggested National River Assessment for fish bioaccumulation is indicated in **Table 12.**

Human Health Risk Assessment (Level 2)

If a fish of x kg's has a body load of μg/kg what will the human health risk be if a person of x kg eats x grams of fish x days per year? The Human health risk assessment fish bioaccumulation protocol, if implemented, will be able to answer this question.

The major areas where the fish are exploited for protein dietary supplemention should be identified and the fish assessed for bioaccumulation body loads. This would include subsistence and recreational fishing and fisheries where fish are utilised as a protein source. This is a form of a chronic assessment.

The fish from rivers or impoundments can then be rated according to the human health risk assessment and recommendations made on the suitability of the fish or mass of fish that would be safe to eat over a period of time. The results of these fish surveys can then published in a pictorial form in a variety of popular publications such as newspapers, fishing journal and entrances of fishing resorts.

Impact Assessment (Level 3)

In order to determine potential impacts of an effluent (point and diffuse) or a development fish tissue loads can be used to determine the possible impacts by comparing a reference upstream site with a fish from a down stream site. Fish are mobile which makes this approach difficult unless a natural or a man made barrier (waterfall, weir, dam etc.) occurs. Fish in cages can also be used by being placed upstream and downstream of a potential impact. The national bioaccumulation protocol results can be used as a comparison or baseline values per species and tissue and compared to the results of this impact assessment.

The following steps should be used for using fish bioaccumulation in impact assessment (**Figure 2**) :-

- understand the catchment and the dynamics that occur
- baseline water quality
- expected impact
- select sites

The frequency will be determine but should be at least seasonal and flow dependant remembering that the lowest assimilative capacity occurs at the lowest flow season.

- select species and tissues according to expected impact
- determine downstream user requirements
- health risks
- whole effluent toxicity
- chemical speciation and bioavailability of pollutant
- link impact assessments with other biological monitoring indices such as SASS, IBI.

The following steps of the proposed bioaccumulation protocol should be undertaken in order to ensure that the correct data is collected at the right rime and at the required level (**Figure 2**).

5.2 Catchment or systems approach

The sample sites chosen will depend on a thorough catchment situation analysis of potential and actual point and/or diffuse sources of pollution. In seasonal and/or regulated rivers, dam or weirs, are good places for fish sampling. Sites should be chosen downstream of potential sources of pollution and must be easily accessible year in and year out.

5.3 Monitoring system design

Choose sample sites

The sampling sites will be determined largely by the river system in each catchment (weirs, waterfalls, accessibility etc.). Further refinement of the sites will also be determined by the level of monitoring to be undertaken:-

Level 1 : National River Health Assessment will for example use a broader scale with respect to the number of sample sites and sample tokens. The sites chosen will probably only be at the end of a specific order of a river (i.e. before the confluence of two major rivers). The frequency of sampling would also be longer and would be around 5 years (**Table 12**).

Level 2 : Human Health Risk Assessments would have a more specific monitoring system design dependant on needs defined by a preliminary or scaping assessment. If a specific body of water is being used for protein supplementation (via angling) then the human health risks need to be determind. If a human health risk is predicted then the monitoring programme design will need to be customised to effectively determine the seventy of the human health risk.

Level 3 : Impact Assessment monitoring programme design would have the most intense monitoring programme. The resolution and frequency of sampling etc. could be from days to months (**Table 12**).

Number of samples to be taken

A general approach with respect to the number of samples to be taken per level is given in **Table 12.**

There is a high variability in tissue loads within the same species at the same site which should be taken into account when planning the bioaccumulation monitoring programme. This aspect needs to be thoroughly discussed with a statistician before the sampling commences as part of experimental design. The specific requirements of the monitoring programme must also take into account the catchability of the fish. the large size of tissues required for analysis and the high costs of analysis. Furthermore the abundance and availability of fish in some rivers in South Africa is low making the collection of fish difficult. Care must also be taken in not over exploiting fragile fish populations through over zealous destructive capture techniques and too frequent monitoring programmes.

Variable selection

Table 12 indicates the suggested protocol for variable selection for bioaccumulation.

The choice of variables to be monitored will vary from catchment to catchment and from site to site depending land use.

Actual pesticide usage databases will assist variable selection as well as interviews with extension offices of the Department of Agriculture. Metal load estimates from industrial and mining effluents can be determined with assistance form the regional DWAF office. Literature reviews of pesticide and metal accumulatory capabilities needs to be done before variables are selected.

Frequency of sampling

Level 1: It is suggested that for pesticides and metals that the bioaccumulation studies of fish in South African Rivers the National River Health monitoring should takes place every five years. This could be phased in with initial emphasis being on priority rivers as determined by DWAF and conservation organizations.

Level 2: Sampling frequency would be determined by the health risk severity.

Level 3: Sampling frequency would be dependant on the specific objectives of the study as well as the site (river or dam). Initially at least quarterly or until the impact has been determined, the frequency can then be refined.

The timing of sampling of these levels will be dependant on the flow regime in the rivers. During the breeding season (summer) certain species of fish migrate making catching difficult as well as the fish absorbing their abdominal fat and using this reserve for breeding purposes. The best season for maximum concentrations of fat in fish would be pre-breeding when the fish accumulate extra fat reserves for breeding.

Specific tissues

The size of the fish caught will determine the amount of tissue available for analysis. For pesticide analysis *ca* 20 g (wet weight) of tissue are necessary. For metal analysis *ca.* 1 g (wet weight) of tissue is necessary.

The specific tissues to be taken will depend on the purpose of the study (**Table 12**), for example:-

Metals

Level 3 : (Impacts Assessments): Gills and liver are suggested for metals.
Level 2 : (Human Health Risk Assessment): The suggested tissues are muscle and skin.
Level 1 : (National River Health Assessments): Suggested tissues are liver, gills and gonads. For long term studies (trends): liver (iron, copper, cadmium), vertebrae (nickel), intestine (chromium, manganese), gonads (zinc, aluminium), skin (lead).

Pesticides

Level 3 : Gonads - testes (pre-breeding season) and liver are suggested.
Level 2 : The suggested tissues are flesh and fat (associated with fatty muscle).
Level 1 : Gonads : (BHC, DDT, DDE, DDD, Dieldrin) and fat (BHC, DDT, DDE, DDD, Dieldrin).

Trophic levels of fish used for bioaccumulation studies.

Due to the patchy distribution of fish species in South Africa it is of benefit to select specific trophic levels of fish rather than species.

Metals

Level 1 : It is proposed that for metals detritivorous or omnivorous species of fish be collected.
Level 2 : Utilized or most eaten species.
Level 3 : Most abundant species of fish (omnivore) or fish of conservation importance.

Pesticides

Level 1 : It is proposed pesticides that piscivorous or omnivores are collected for persistent residues.
Level 2 : Utilized or most eaten species.
Level 3 : Most abundant species of fish (omnivore) or fish of conservation importance.

5.4 Timing of sampling

Levels 1 and 2 : April and September (for the summer rainfall areas) and November to March (for the winter rainfall areas). This enhances the catch per unit effort, reducing sampling time and manpower.
Level 3 : The survey will be needs driven.

5.5 Sampling method

The fishing methodology will depend on the river geomorphology, flow, river width, manpower and equipment. Seine nets would be preferable as only the fish needed can be sampled and the rest returned unharmed. Gill nets can also be used if the river is flowing too fast, its bottom too rocky, too much debris on the bottom or sides or if the river is too deep. For impact assessment cages could be used with fish being placed upstream and downstream of the potential impact.

5.6 Dissection and storage of tissues.

Tissue terminology should be standardised for example muscle (muscle tissue without the skin and scales and deboned as far as possible etc.).

Tissues should be dissected in a clean environment and using clean dissection equipment in order to prevent contamination.

The samples should be stored in clean, clearly labelled glass or plastic containers in a freezer at -5 °C . The samples should not be kept in storage for long periods before analysis is undertaken.

5.7 Analysis of samples

Analytical methods

Need to use Standard Methods (1989).

Quality control

Analysis should be undertaken at accredited analytical facilities using internationally accepted standards.

5.8 Data storage and reporting of results

Data storage

The data base generated by this proposed national bioaccumulation programme must be:-

- coordinated by DWAF
- data bases - open and seamless
- housed at a central and accessible institution
- updated regularly
- free of charge
- available through the internet

Reporting

The bioaccumulation monitoring programme must be designed as a management information system and used as a Decision Support System to compliment DWAF's national water resource management strategies.

The results must be made public in an easy to understand format. Indices need to be developed in order to convey the status of the fish, the river health etc. so that the whole populous of South African can understand what the results mean and what they can possibly do to improve the water quality and aquatic ecosystem status of our rivers.

5.9 Management decision support

Management interventions

If management targets are set then the results of the bioaccumulation monitoring programme must be used to determine the success of the catchment management plan and suitable management interventions undertaken until such time as the targets are reached.

The results of the bioaccumulation assessment can be used as to audit how effective the catchment management interventions have been over a period of time.

6. RECOMMENDATIONS

6.1 Biological Monitoring Development Needs

There is a large amount of development. verification and implementation required before biological monitoring in South Africa can take its rightful role in assisting water quality management. This development needs to be facilitated and controlled so that the aims and objectives of DWAF's policies and mission statement with regards to the aquatic ecosystem are met. With the limited time and money available this development needs to be well co-ordinated (Heath 1993).

6.2 Linkage of Bioaccumulation Studies with Human Health Risk Assessment

International data bases on human health risk assessment must be accessed to determine the risks associated with the human consumption of fish tissues contaminated with pesticide and metals. This is an important issue not only for freshwater fish but for estuarine and coastal fish that are a staple protein source for a large proportion of our population.

6.3 Ongoing Refinement

The bioaccumulation protocol needs to be re-assessed and refined after initial application in rivers. The tissues selected for specific bioaccumulation studies as well as the trophic levels selected for need to be verified in a variety of riverine ecosystems.

6.4 Standardization of Techniques

The analytical techniques used to determine pesticides and metals need to be standardized for comparative purposes. These standard techniques should include sampling procedures. tissues and species used for bioaccumulatory studies. The data reported should also be in standardized units for example $\mu g/g$ or mg/kg dry weight. This standardization will reduce possible errors in converting from other units.

6.5 Custodian of Results

The data collected on fish and other organisms in terms of bioaccumulation studies should be stored at central institution whose responsibility it should be to update and do quality control on the data collected. DWAF is ideally suited for such a role as they already collected the National, Regional and Compliance monitoring water quality data which should be linked to bioaccumulatory data.

6.6 All Bioaccumulatory Studies Synthesized

The synthesis of all the varied bioaccumulatory studies is imperative. As different organisms and rivers have been studied by different organizations it is now timeous to integrate and interpreted all these studies in order to not have any duplication of studies, and to decide on what organism, tissue, species, method that should be used in a state of nation assessment.

6.7 Research Needs

- Controlled laboratory studies to determine the pesticide and metals uptake rates and response times in fish tissues in typically high turbidity water.

- Correlate pesticide and metal sediment loads with fish tissue loads. High turbidity rivers in South Africa could result in the majority of the pesticides and metals loads settling into the sediments rather than been transported in the river for long distances.

- Tissue selection needs further refinement especially gills, intestine etc.

- Sublethal behavioural changes in breeding success, breeding migrations should be monitored in rivers with high pesticide and metal loads. This would require a combination of laboratory experiments and fish population dynamics and behaviour studies in non-turbid rivers.

- Fish population dynamics (fecundity, mortality etc.) should be compared with bioaccumulated body loads of pesticides and metals.

- Bioaccumulation fish body loads need to be compared with fish health indices.

- Bioaccumulation must be linked in a cost effective manner with IBI and fish health index.

- Areas of aquatic ecosystems (freshwater, estuaries and coastal zone) with high bioaccumulation rates need to be identified nationally and the local subsistence populous informed and educated about possible health risk. Standard practises such as gutting all fish and throwing away fatty tissues should be instilled in these populations.

- Analytical techniques need to be refined in order to allow smaller tissues samples to be analysed especially for pesticide residues. Methods should be develop to allow for the analysis of new generation pesticides. These methods must be standardised and interlaboratory studies undertaken to compare results.

- Natural background origins of metals in rivers needs to be quantified according to the local soil types, geology and land disturbances.

- User friendly, easily understandable icons or cartoons need to be developed as an educational tool for grass roots education at primary schools. Bioaccumulation indices need to be developed for the general public so as the current status of our rivers can be easily understood.

Biological monitoring in South Africa will improve the current water quality management programme. Fish as a bioaccumulator of pollutants can be used to verify the effectiveness and validity of the currently used water quality management programme.

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TERMS OF REFERENCE

The aims of the study, as agreed in the original contract between WATERTEK, CSIR and the Water Research Commission were as follows:

1. To integrate information from, and collaborate with, researchers studying the ecological features of five rivers in the Mpumalanga and Northern Provinces that flow through the Kruger National Park (KNP) and one Western Cape river. Existing data and study sites with habitats specific to selected species of fish will be used in order to maximize fishing efforts.

2. To utilize information from completed and presently undertaken catchment studies of the selected rivers, in collaboration with researchers currently working in the field, to determine the point and possible diffuse sources of pesticides and metal pollution. Existing land usage, estimates of the pesticides most commonly used and the specific metal variables associated with the industries in each river catchment will be used to select the specific variables for analysis.

3. To catch selected species of the larger indigenous fish in these rivers, at sites where pesticide and/or metal pollution is expected. Techniques developed by the researcher in charge of this proposal will be used to selected specific species of fish as well as the particular fish tissues in which pesticide and metal levels will be determined.

4. To establish the current body loads of pesticides and metals present in the larger species of indigenous fish in the selected rivers for the period of study.

5. In collaboration with other researchers and the Department of Water Affairs & Forestry, the current fish body loads and monitoring techniques developed in this report will be proposed for the implementation of a National Bioaccumulation River Surveillance Programme for pesticides and metals in South African rivers.

Anticipated benefits

- Factual information on pesticide and metal levels in selected indigenous fish in five rivers that flow through the Kruger National Park and a major Western Cape river.

- Factually based estimates, taking the whole catchment area into account, as to the origin and significance of particular pesticides and heavy metals.

- Current fish body loads which can be used for future comparison and for other South African rivers.

- Estimates of the effects that pesticide and heavy metal pollution have on the larger indigenous fish populations of the selected rivers. Extrapolations will be made up the food chain to the top predators of these systems, and the likely effects on these organisms will be estimated.

- Guidelines as to how a surveillance monitoring system may be implemented for other South African rivers.

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The Water Research Commission is gratefully thanked for its funding of this project, as are the members of the Steering Committee for their contribution to the project.

Dr Steve Mitchell has supported the project very effectively, from its initial stages of proposal development through to field assistance.

The Steering Committee responsible for this project consisted of the following persons:

Dr S A Mitchell	Water Research Commission
Dr P C Reid	Water Research Commission
Ms A M du Toit	Water Research Commission - secretariat
Dr C J Kleynhans	Transvaal Provincial Administration, now Department of Water Affairs & Forestry
Dr A Deacon	National Parks Board
Dr P L Kempster	Department of Water Affairs & Forestry
Prof H J Schoonbee	Rand Afrikaans University
Prof H du Preez	Rand Afrikaans University

Dr Peter Ashton assisted with site selection and project design. Prof Hein du Preez made several editorial comments for the final report.

The, then, Directorate of Environmental and Nature Conservation of the Transvaal Provincial Administration has actively collaborated in the fish study, by providing a researcher, a technician and a fishing team to assist in the collection of fish in the Letaba, Olifants and Crocodile Rivers.We appreciate their support, without which it would have been well-nigh impossible to sample the fish at the selected sites.

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1. INTRODUCTION

1.1 Water in South Africa

One of the most limiting natural resources in South Africa's is water (DWAF 1986). The country's rivers are often short and usually have high seasonal flow regimes (O'Keeffe 1986). South Africa's average annual rainfall of 500 mm is only 60 percent of the world's average. Sixty five percent of the country receives less than 500 mm of rain annually and 21 percent receives less than 200 mm. The rain is poorly distributed, particularly relative to areas experiencing growth in demand. Only a narrow region along the eastern and southern coastlines is moderately well watered, while the greater part of the interior and western part of the country is arid to semi-arid (DWAF 1994). Over most of the country the average annual potential evaporation, which ranges from 1 100 mm in the east to more than 3 000 mm in the west, is well in excess of the annual rainfall, which reduces the surface runoff greatly.

In order to ensure an adequate water supply South Africa has build a number of large dams which are used as storage reservoirs for potable water supply and irrigations schemes. Coupled to these dams are major interbasin transfer schemes that ensure that the present water demands in the centre of the country are met. There are currently some 17 water boards in South African that are bulk suppliers of treated water for all types of uses (potable, industrial, agricultural and mining).

More than 12 million people in South Africa do not have access to adequate supply of potable water and nearly 21 million lack basic sanitation (DWAF 1994). Demands for fresh water will increase dramatically over the next two decades, as South Africa's population is expected to double by the year 2050 (Davies & Day 1986). Couple to the increasing population the policy of the Reconstruction and Development Plan (RDP, ANC 1994) is that water is a basic human right and that each person should receive at least 25ℓ per day at a maximum distance of 200 m from their dwellings. This water should also be of such a quality that it is in accordance to the currently accepted minimum standards with respect to health related chemicals and microbiological contaminants (DWAF 1994). This emphasizes the urgent need for careful management and conservation of our scarce water resources in order to maintain their ecological sustainability and fitness for use.

There is an increasing public awareness of the environmental importance of water and the importance of not destroying the natural environment when developing water resources. In semi-arid climates it is very important to find a balance between water resource development and maintaining the natural environment (DWAF 1995). In the present Water Act, (Act 54 of 1956) the environment is not regarded as a legitimate user of water in the eyes of the law. Recently the needs of the environment, particularly the riverine environment, have been increasingly taken into account and the impact of development is beginning to be taken seriously. The proposed new water act proposes that the environment is the resource base which needs to be protected. Only once this resource reservoir has been protected and sufficient water is allocated to it will the other users be catered for. The environment will no longer be considered as a user of water, competing with other users such as industrial, agriculture, potable, recreational and municipal users. Once the legal ramifications have been sorted out as to how to compensate for existing historical water user rights and this water law is passed the natural environment will be adequately protected in a sustainable manner.

The major sources of pollution of South African waters originate from point discharges (factory effluents, waste water treatment works) and diffuse runoff (agricultural, urban and mining). The most important pollutants that occur in South African inland waters are microbiological (waste water works, unreticulated sewage and formal and informal urban runoff), sulphates, low pH and high conductivities (mine related), increasing salinity (mine and farming related), metals (industrial effluents and mine discharges) and organic enrichment (waste water works, unreticulate sewage and farming practices) and pesticides (agriculture and industry).

Pollution of South African surface waters by pesticides and fertilizers, mainly of agricultural diffuse origin, and by metals, mainly derived from an industrial point source origin, is a cause of increasing public concern. This concern has escalated rapidly in recent years following major fish kills in Mpumalanga and Eastern Cape rivers.

Chemicals (pesticides and metals) released into the environment are transported and redistributed among the different compartments in the environment, with transport across membranes into organisms being one of the processes. The impacts of these pollutants on aquatic ecosystems are either dramatic and obvious, due to immediately lethal doses, or insidious due to gradual accumulation of lethal concentrations in the body tissues and organs of otherwise healthy organisms. In the latter case, ecosystems quietly and dramatically change. The insidious bioaccumulation which lies at the root of public concern and fear, forms the core of this research.

1.2 Use and Fate of Pesticides in the Environment

Pesticides are chemical components that kill pests and include, amongst others, acaricides, algicides, anthelminthics, avicides, ovicides, fumicides, fungicides, herbicides, insecticides, molluscides, piscicides, nematicides and rodenticecides. Pesticides afford remarkable benefits to mankind not only by increasing crop yields and protecting forests but also by controlling arthropod vectors of serious human disease.

It is well known, however, that residues of persistent pesticides, especially those of organochlorine insecticides, are found in terrestrial and aquatic environments, including their constitutive organisms. Since these chemicals are highly lipid soluble, lengthy exposure to them result in their high accumulation in organisms, and hence they may produce adverse effects on ecosystems. These phenomena are clearly demonstrated in the hydrosphere rather than in the atmosphere and the lithosphere because of the high density of organisms and complicated food webs in the hydrosphere (Miyamoto *et al.* 1990).

Pesticide contamination of running waters can occur in many different ways and from many different sources, and may be of short duration or it may be prolonged (Muirhead-Thomson 1989). The following categories are the potential sources of pesticide contamination of surface waters:

(a) Direct application of pesticide to water body (dams and rivers) in order to control undesirable fauna or flora (viz. fish, biting black fly, aquatic weeds, mosquitoes, aquatic snails, etc.)

(b) Aerial spraying against terrestrial pests causes underlying water bodies to be contaminated by such spraying operations

(c) Contamination by accident, spillage or careless disposal of surpluses, is liable to occur in any country where pesticide is used on a regular basis

(d) Contamination by pesticides from industrial source is well exemplified by the incorporation of insecticides in the textile and wood industries

(e) Contamination by drainage from agricultural or Forest Land is probably the major contribution in countries where aerial spraying is not well developed

(f) Contamination by autumn - shed leaves is a significant source associated with forest areas

(g) Contamination by aerial spraying by means of natural forms of transport such as wind or rain

The fate of a pesticide in the environment is, however, governed by many varied properties of both the pesticide and the environment that the pesticide is applied to (**Figure 1**). These complex interactions will determine the fate of the pesticides in the environment as well as the bioaccumulation potential to fish.

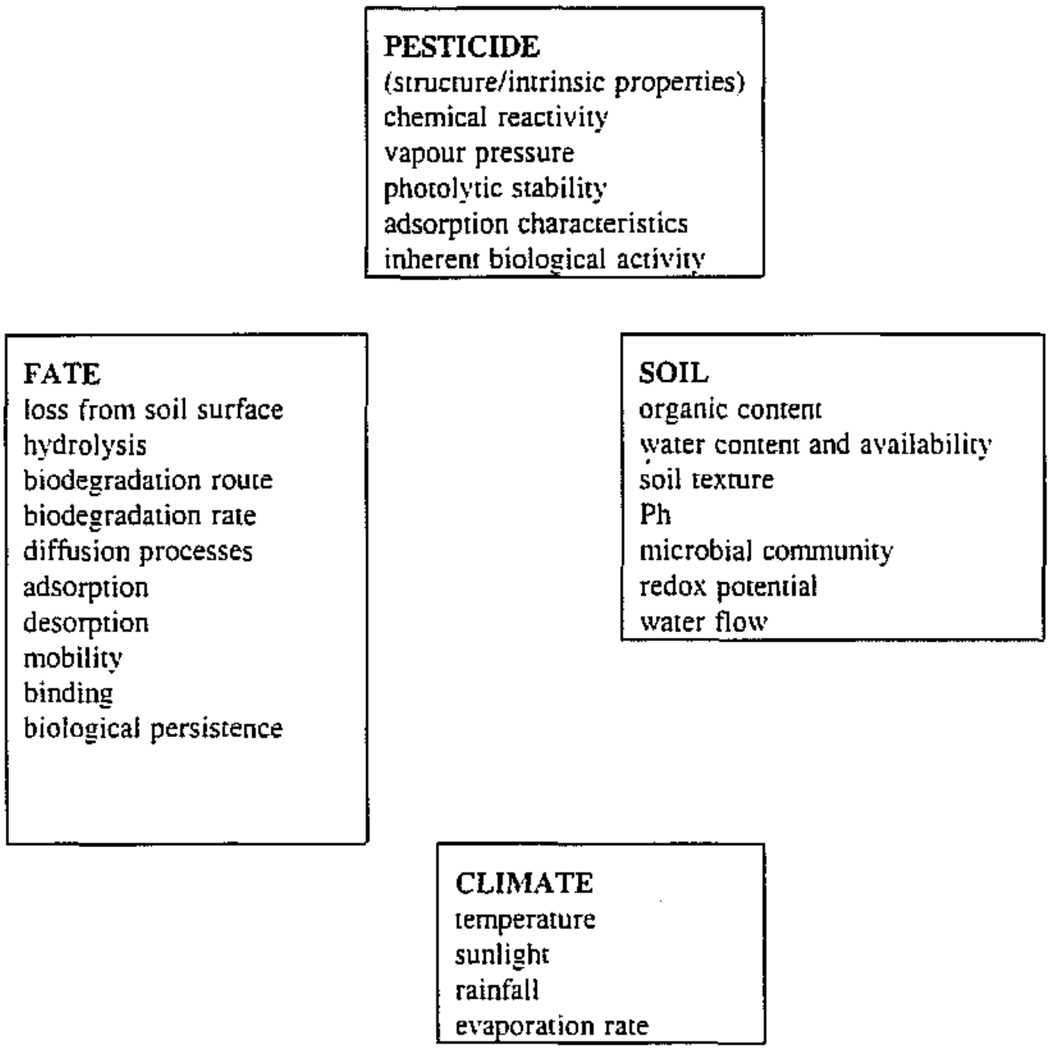


Figure 1: Factors governing the fate of pesticides in soil (Arnold & Briggs 1990).

1.3 Fate of Metals in the Environment

Metals in the environment, apart from having a geological origin, can also originate as point sources from industrial pollution or diffuse sources from agricultural and mining origins. Mining (diffuse) and industrial (point) effluents are the general sources of elevated metal concentrations in river water. Fish can uptake metals from the surrounding water through various pathways such as via the gills and skin, via food and non food particles ingested through water in the intestine. It is usually the ionic forms that produce the immediate fish mortalities, while complex metal compounds tend to act by accumulation in the body tissues over a considerably longer period of time (Ellis 1989). The approximate order of the toxicity of metals, based on published data, is given in **Table 1** (Hellawell 1986). Several factors can influence the toxicity of metals, for example, their concentration in water, the form in which they are present (complexed, ionic or organic), the difference in species sensitivity and life cycle stage sensitivity to toxicant, the concentration and type of other toxicant present (the effect of being additive, antagonistic or synergistic) or the condition and quality of the water itself (determinants such as dissolved oxygen, pH, temperature and water hardness). Generally the toxicity of metals increases with increasing water hardness (Ellis 1989).

Table 1: **Tentative order of toxicity of metals (Hellawell 1986).**

Highly toxic				**Decreasing toxicity →**							
Hg											
	Cu	Cd	Au?	Ag?	Pt?						
		Zn									
			Sn	Al							
				Ni	Fe^{3+}						
					Fe^{2+}						
						Ba					
							Mn	Li			
							Co	K	Ca	Sr	
										Mg	Na

All metals are toxic to aquatic organisms when present at elevated levels, causing direct or indirect affects such as histological damage or a reduction in the survival, growth and reproduction of the species (Heath 1987). A detailed discussion on the effects is presented in Section 5.3.1.

1.4 Biological Monitoring

The rapid international growth of environmental monitoring over the past two decades has come about due to man's interest in pollution being centred on its effects on living organisms. Public pressure to improve the environment, coupled to the declining international water resources quality, has resulted in biological monitoring enjoying even greater interest in recent times.

It is now generally understood that measurements of only the physical and chemical attributes of water cannot be used as surrogates for assessing the health of an aquatic system (Karr and Dudley 1981). Chemical monitoring misses many man-induced disturbances, such as flow alterations and habitat degradation, that impair use of the aquatic habitat. Furthermore, the monitoring of water quality variables often does not reflect short-term events that may play a critical role in determining the ecosystem health. It is now widely accepted overseas that biological assessment techniques should be incorporated into water quality management policies in order to adequately protect aquatic resources. The implications of biological monitoring are that if the water is environmentally healthy it is consequently safe for all other users.

Sustainable resource management requires that the biosphere be viewed as an entity consisting of three integrated component namely social, economic and environmental. No compartment can be sacrificed for any other without a decrease in the overall quality of human life. The guiding principle for integrating these compartments is ecosystem health - the health of human populations and their environment (Vallentyne and Munawar 1993). In other words, healthy places result in healthy people and healthy people in healthy places (Hohls 1996).

For effective use biological monitoring protocols need to be integrated into water quality monitoring programs in order to generate the information that allows effective management of aquatic resources. Biological data must be integrated with physical and chemical data in order to provide meaningful environmental information. A typical Ecosystem Health Assessment Programme is presented in **Figure 2** (Roux 1994).

The Department of Water Affairs and Forestry (DWAF) has followed the current world trend, and has moved towards an integrated and cost effective assessment of aquatic ecosystem health. The information generated from a broad spectrum of biological monitoring options will allow an increase in ecological focused management of our waterways. The Department of water Affairs and Forestry has published a White Paper outlining its fundamental policy on the environment (DWAF 1994) as part of its approach to managing water supply and sanitation. The key principles to this Paper are:-

- Protection and conservation of the natural resource base is imperative.

- The environment should not be regarded as a "user" of water in competition with other users, but as the base from which the resource is derived and without which no development is sustainable.

- The concept of water as having economic value should be extended to it also having intrinsic environmental value.

ECOSYSTEM HEALTH

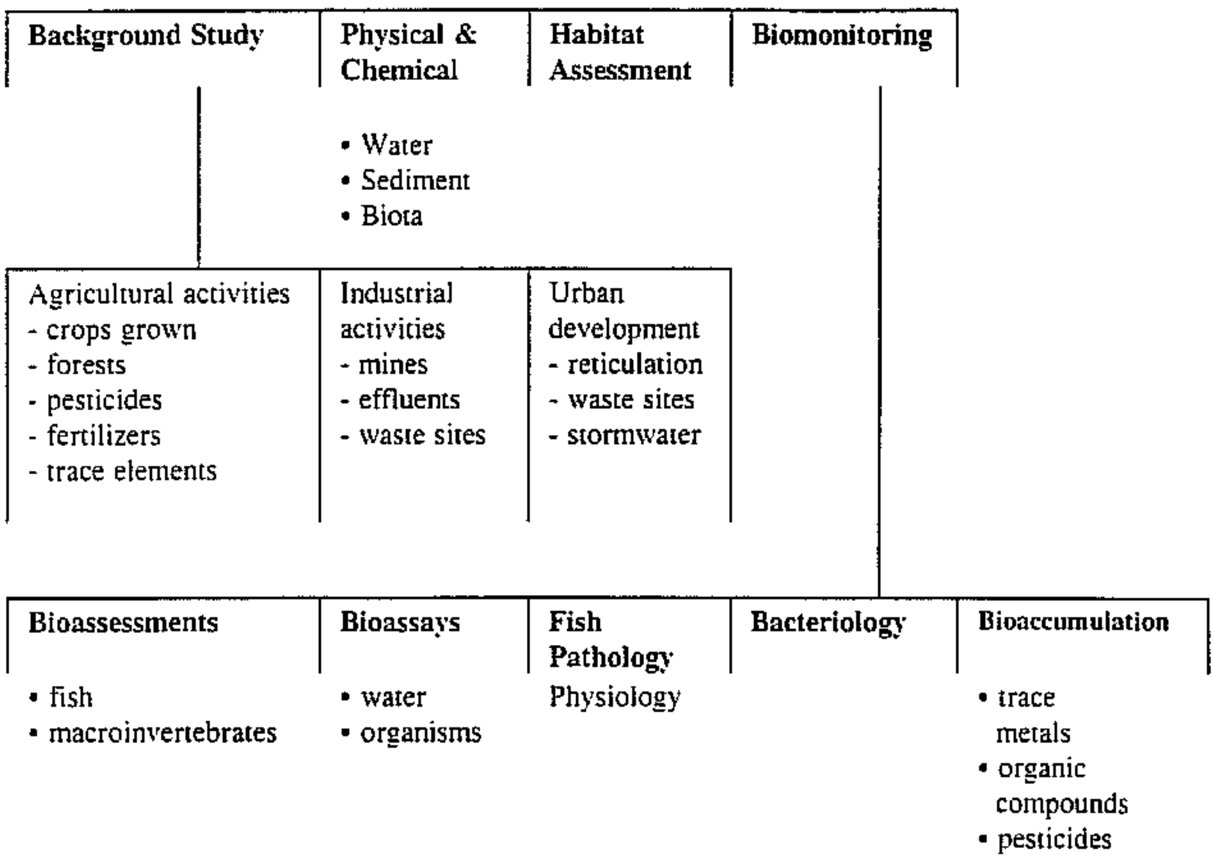


Figure 2: **An Ecosystem Health Assessment Programme for management of water quality and aquatic habitats (Roux 1994).**

The present study focuses on one component of the biomonitoring program namely the bioaccumulation of pesticides and metals in aquatic species. Specifically in the tissues of fish species from six rivers in South Africa that have differing loads of metals and pesticides. A broad definition of bioaccumulation as used in this study is seen below:-

Bioaccumulation definition:-
General term describing a process by which chemical substances are accumulated by aquatic organisms from water directly or through consumption of food containing the chemicals.

1.5 Fish as Biological Monitors

Aquatic organisms tend to integrate all the stresses placed on the aquatic system and reflect combined effects over an extended period of time. Aquatic organisms are recognized as bio-accumulators of pesticides and heavy metals and consequently can be used for monitoring of pesticides and heavy metal eutrophication.

Fish are considered to be a suitable component of the aquatic system to monitor because they integrate the effect of detrimental environmental changes as consumers which are relatively high in the aquatic food chain. Fish as indicator organisms for biological monitoring have a high public profile and consequently are used extensively for conservation status and bioaccumulation studies.

Fish are good organisms to use in biomonitoring and specifically bioaccumulation because : -

(a) They are relatively long-lived and mobile, are good indicators of long-term effects and habitat changes.

(b) Fish communities usually indicate a range of species representing a variety of trophic levels. They tend to integrate effects of lower trophic levels; thus fish community structure is reflective of integrated environmental health.

(c) Fish are top of the aquatic food chain and are eaten by man, making them important subjects for assessing contamination.

(d) Fish are relatively easy to collect and identify to the species level. Most specimens can be sorted and identified in the field and released unharmed.

- Environmental requirements of common fish are comparatively well-known.
- Life history information is known for some species.
- Fish distribution information is available.

(e) Aquatic life uses (water quality standards) are typically characterized in terms of fisheries (cold water etc - USA EPA 1989). Monitoring fish communities provides direct evaluation of 'fishability', which emphasizes the importance of fish to anglers and commercial fisherman.

(f) There are 50 species of fish regarded as endangered species in the South African Red Data Book (Skelton 1987).

Fish do, however, have the following shortcomings as indicators of pollution:-

- they are mobile and can move away from pollution
- their mobility means that the if a fish is caught in an area it might not reflect the pollution of that area
- fish are able to regulate certain elements and by so doing the levels in their bodies might no be a true reflection of the surrounding environment

It is well known that fish accumulate metals in their tissues and organs when they are exposed to metal polluted water. The uptake of metals occurs via the skin and gills whilst the intake via contaminated food and drinking water. After uptake metals are transported in the blood and thus brought in contact with the organs where the metals can bind to proteins and amino acids. The total intake of all metals are not all accumulated as the levels of most metals are regulated by certain biological strategies and excretion of metals occur via a variety of pathways. Bioaccumulation of metals is also influenced by a variety of environmental factors and certain factors relate to the organism itself.

Biomonitoring indices originating from fish are, however, not far advanced in South Africa at present. Community indices such as the Index of Biotic Integrity (IBI) are at present being refined on regional zoogeographical zones (DWAF 1996).

It is due to the ability of fish to accumulate pesticides and metals that fish were collected to determine the current levels of these pollutants in the fish of the selected rivers.

1.6 Why Was This Study Undertaken?

At the workshop on 'Preliminary Water Quality Guidelines for the Rivers of the Kruger National Park' (Moore *et al.* 1991), the inadequacy of our present knowledge of pesticides and metals in South African rivers was highlighted as a major research priority. This research project therefore deals with the **Bioaccumulation** aspects of **Ecosystem Health Assessment** in which the **body loads of fish** are sampled for **heavy metal** and **pesticide accumulation**.

The sampling sites were depend on the current understanding of whole catchments and the locations where diffuse and point sources of pollution were expected. The expected variables of concern were analyzed in samples of river water and fish tissue. This research plans to integrate information from, and collaborate with, existing catchment studies and research projects being undertaken on five rivers which flow through the Kruger National Park and one Western Cape river. The Mpumalanga and Northern Province rivers that will be studied are: the Letaba River (mainly intensive agriculture along its banks with some industrial pollution, as well as being seriously affected by water abstraction in winter); the Sabie River (agriculture and a limited number of industries); the Luvuvhu River (subsistence agriculture and erratic seasonal flows); the Crocodile River (most intensive irrigation system in South Africa with numerous point and diffuse sources of domestic and industrial pollution) and the Olifants River (intensive and subsistence agriculture and numerous point and diffuse sources of industrial pollution). The Western Cape river chosen viz. the Berg, is a river with intensive agriculture, aquaculture and industry.

Specific species of fish as well as specific tissues were evaluated for use in the biomonitoring of eutrophied rivers in South Africa. The species of fish selected had to be readily available (i.e. abundant), be found over a large area (i.e. can indicate pollution levels along the length of a river) and be hardy (i.e. not too sensitive to pollution loads - can accumulate them without being seriously affected).

This report focuses on the bioaccumulation of pesticides and metals in indigenous fish species from six southern African rivers. The body loads (1989 - 1993) of pesticides and metals in the fish of the selected rivers will be compared with each other and literature values. A protocol will be tested and, if suitable, can be used to monitor South African rivers for pesticide and metal bioaccumulation levels in fish tissue.

2. GENERAL DESCRIPTION OF THE STUDY AREAS

Five of the river catchments (Crocodile, Letaba, Luvuvhu, Olifants and Sabie) studied have their origins outside the Kruger National Parks in Mpumalanga and the Northern Province, flow west to east, before entering Mozambique and finally the Indian Ocean (**Figures 3 and 4**). The Berg River, in the Western Cape, was used as a test river from the winter rainfall region to determine if the techniques used in the other catchments could be successfully applied.

The characteristics (land usage, surface areas, soil types, geology etc.) of these catchments are summarised and compared in **Tables 2 to 5**.

2.1 The Letaba River

The Letaba River which originates in the escarpment Drakensberg mountains near Haenertsburg in the Northern Province has a catchment area of ca. 13 200 km^2 (SRK 1990, **Figure 5**). The Letaba River has two main tributaries namely the Klein Letaba and the Groot Letaba. The main dams in the Klein Letaba are the Mid-Letaba and the Hudson Ntsanwisi dams. The major dams on the Groot Letaba River are the Ebenezer and Tzaneen dams. The Tzaneen Dam regulates the flow of water down the Groot Letaba River mainly for irrigation purposes. Their are several weirs and instream dams in the Groot Letaba River of which some are controlled by the Groot Letaba Irrigation Board and used for irrigation storage. These weirs and dams are Junction Weir, Pump Station Weir, Prieska Weir, Slab Weir, Mingerhout Dam and Engelhardt Dam (**Figure 5**).

The main geological units underlying the catchment are; Barberton, Murchison, Giyani, Beit bridge, Meihardskraal granite, Sand river gnies, Suurberg, Drakensberg, Lebombo, Transvaal, Rooiberg and Griqualand west (**Table 5**). The diversity in geological units is the origin of the four major soil types being found in the catchment namely Glenrosa, Hutton, Mispah and Shortland (DEA 1994, **Table 4**).

Development in the catchment started at the turn of the century in terms of agriculture and afforestation (**Table 2**). Forestation, which occurs upstream of the Tzaneen Dam only accounts for 3,6% of the study area. Irrigation, which accounts for 72% of all water used, supplies at present *ca.* 34 000 ha, with a further 16 000 ha for dryland farming. The major crops in the catchment are citrus, bananas and mangoes (**Table 3**). There are a limited number of industries within the Letaba River Catchment. These include a canning factory at Politsi, Letaba Citrus Processors, Koedoe-Co-op and a Saw Mill. Small industries are located around Tzaneen. The over-utilization of the water in the Letaba River

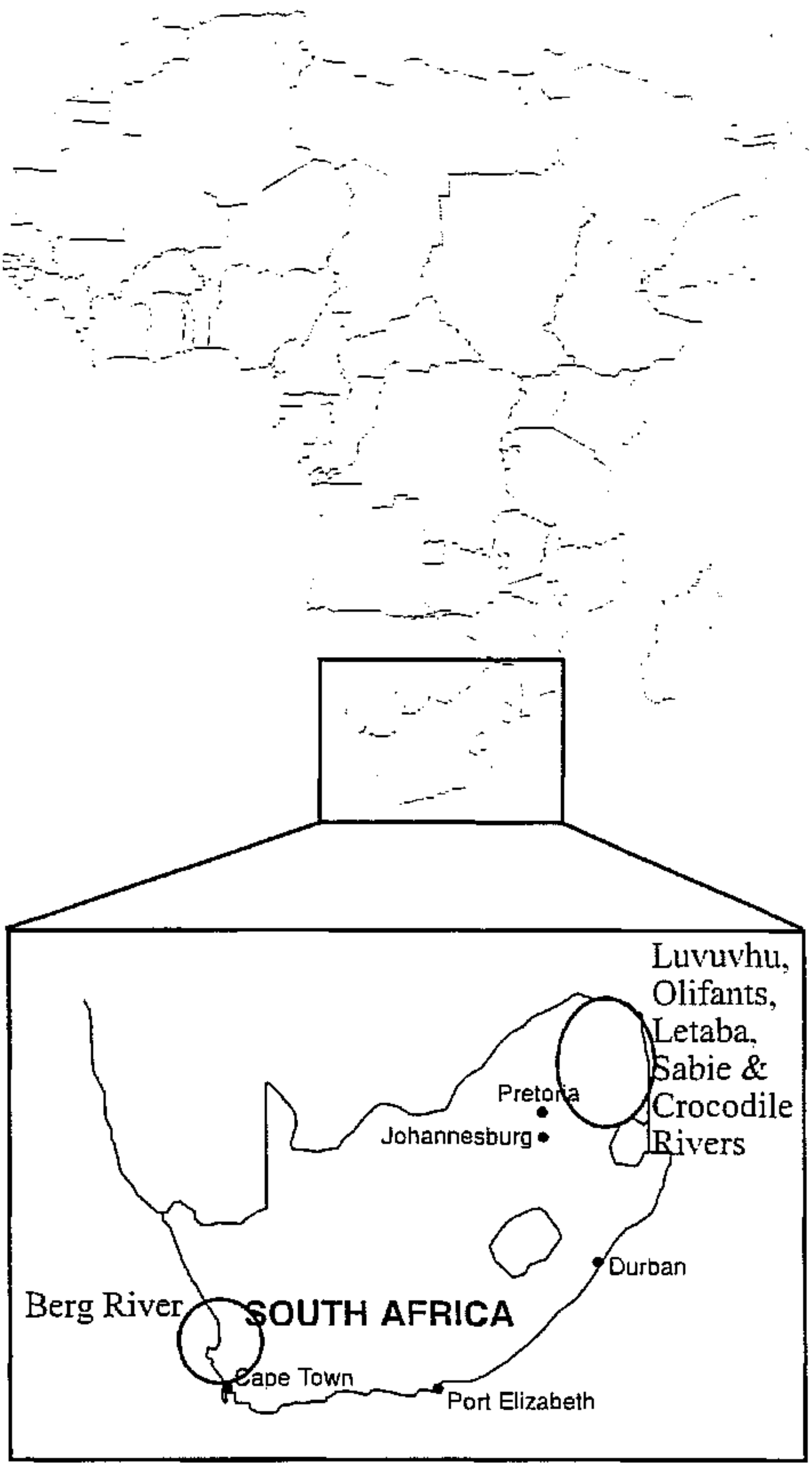


Figure 3: The locality of the study area rivers in South Africa.

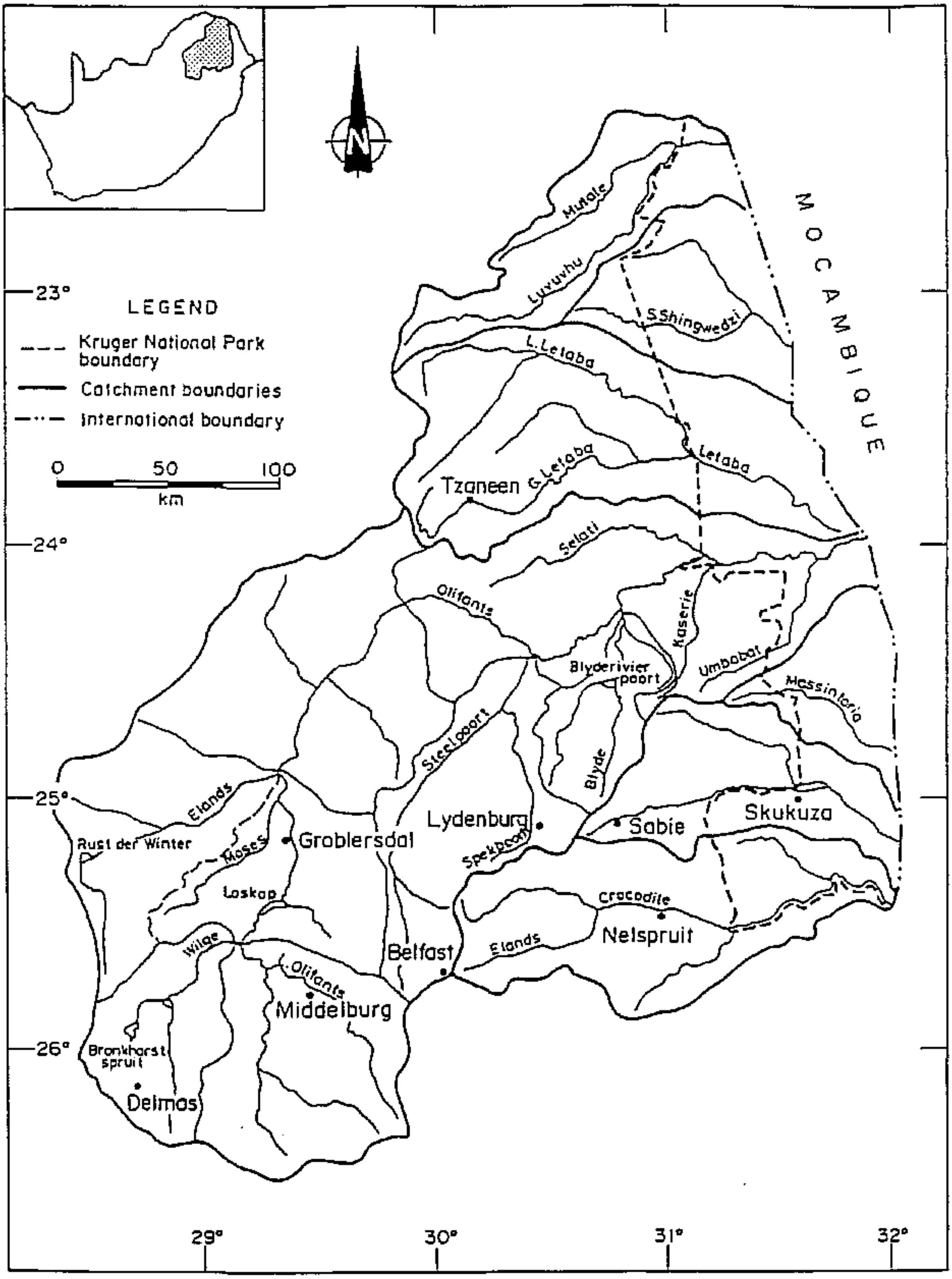


Figure 4: The locality of the five river catchments sampled that flow through the Kruger National Park (from Breen *et al.* 1994).

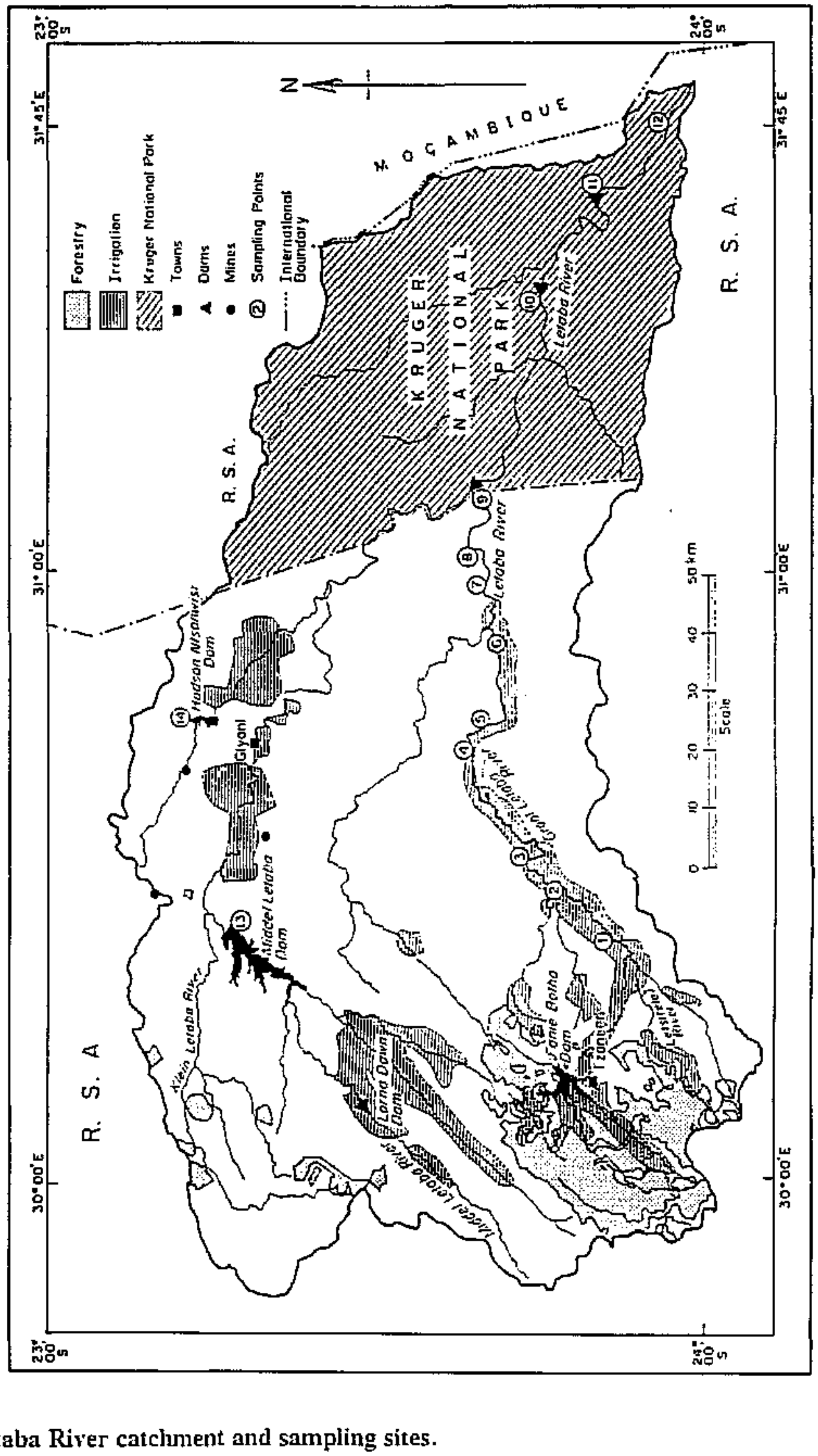


Figure 5: The Letaba River catchment and sampling sites.

catchment. especially due to intensive afforestation and irrigation of sub-tropical fruit has resulted in the once perennial Letaba River no longer flowing in the winter months within the Kruger National Park (Chutter & Heath 1993).

Table 2: Characteristics of the catchments of the study rivers.

Characteristics	Crocodile	Letaba	Sabie	Luvuvhu	Olifants	Berg
Catchment area (km^2)	10 440	13 200	6 437	3 568	54 500	9 000
Irrigated area (ha)	95 000	34 000	11 300	9 000	103 000	7 500
Afforested area (ha)	172 200	47 520	71 100	14 600	72 000	7 500
Dry land agriculture (ha)	290 000	16 000	11 570	subsistence	1.2×10^6	3 267
Mean annual rainfall (mm/a)	879 summer	671 summer	833 summer	731 summer	675 summer	524 winter
Runoff (Mm^3/km^2)	118514 seasonal	59964 seasonal	134314 perennial	89072 seasonal	47475 seasonal	116286 perennial
People/km^2	45.9	92.9	134.8	84.9	84.6	37.4
Industries						
Pulp & paper	✓					
Fruit processing	✓	✓				✓
Saw mill	✓	✓	✓			
Sugar refinery	✓					
Metal refinery	✓				✓	
Winery						✓
Power generation					✓	
Tannery and leather						✓
Small industries	✓	✓	✓	✓	✓	✓
Mining	✓		✓	✓	✓	

Where ✓ = activity occurs in catchment

Table 3: Major crops (✓) grown in the catchments studied.

Crop	Crocodile	Letaba	Sabie	Luvuvhu	Olifants	Berg
Sugar cane	✓		✓			
Bananas	✓	✓	✓	✓	✓	
Citrus	✓	✓	✓		✓	
Mangoes		✓		✓		
Tomatoes	✓	✓			✓	
Vegetables	✓	✓	✓	✓	✓	
Maize	✓			✓	✓	
Avocados			✓			
Tobacco	✓			✓	✓	
Paw Paws	✓	✓	✓	✓	✓	
Wheat						✓
Grapes						✓

Table 4: Dominant soil types in the catchments studied.

Berg	Crocodile	Letaba	Luvuvhu	Olifants	Sabie
Fernwood Rock Swartland	Glenrosa Hutton Shortland Valsriver	Glenrosa Hutton Mispah Shortland	Glenrosa Hutton Mispah Shortland	Arcadia Glenrosa Hutton Mispah Shortland	Glenrosa Hutton Shortland

Table 5: Dominant geology of the catchments of the rivers studied.

Berg	Crocodile	Letaba	Luvuvhu	Olifants	Sabie
Alluvium	Barberton	Barberton	Barberton	Barberton	Meinhardskraal-granite
Sand	Murchison	Murchison	Murchison	Murchison	*Sand river-gneis*
Calcrete	Giyani	Giyani	Giyani	Giyani	Suurberg
Cape granite	Beit bridge	Beit bridge	Beit bridge	Beit bridge	Drakensberg
Malmesbury	Meinhardskraal-granite	Meinhardskraal-granite	Suurberg	Bushveld-complex	Lebombo
Kango	Sand river gneis	Sand river gneis	Drakensberg	Ecca	Transvaal
Gariep	Suurberg	Suurberg	Lebombo	Meinhardskraal-granite	Rooiberg
Table-mountain	Drakensberg	Drakensberg	Waterberg	Sand river gneis	Griqualand-west
	Lebombo	Lebombo	Soutpansberg	Rustenburg	
	Transvaal	Transvaal	Orange river- alluvium	Lebowa	
	Rooiberg	Rooiberg	Sand	Rashoop	
	Griqualand-west	Griqualand-west	Calcrete	Suurberg	
			Meinhardskraal-granite	Drakensberg	
			Sand river gneis	Lebombo	
				Transvaal	
				Rooiberg	
				Griqualand-west	

The study sites used in this study are shown in **Figure 5** and are listed below. Four of these sites viz. Junction, Prieska, Pump Station and Slab occur outside the Kruger National Park at weirs.

Site 1 : Junction Weir, below confluence of Groot Letaba and Letsitele Rivers. Used as an irrigation storage dam and the level fluctuation according to irrigation use.

*Site 2 : Nagude causeway, deep pools and riffles.

Site 3 : Pump Station Weir, river broad and shallow with well established overhanging marginal vegetation

Site 4 : Prieska Weir, broad shallow dam which is drawn down until almost empty in winter

Site 5 : Prieska Farm, fast flowing narrow riffles and backwater pools

Site 6 : Nondweni causeway, deep pool above causeway and shallow riffle below

Site 7 : The Slab, shallow weir which dams up river for ca. 500 m

Site 8 : Camp 3 in Letaba Ranch, deep pools with fast flowing rapids between them

Site 9 : Camp 16 in Letaba Ranch, close to Kruger National Park boundary, shallow riffles between pools

Site 10 : Pools below Mingerhout Dam, broad river bed with base rock. No fish caught here

Site 11 : Engelhardt Dam, broad, deep dam

Site 12 : Drift across river, downstream of Engelhardt Dam, shallow, sandy and low winter flows

Site 13 : Middle Letaba Dam

Site 14 : Hudson Ntsanwisi Dam.

*Site where no fish of a suitable size were caught.

2.2 The Sabie River

The Sabie River is situated in the Mpumalanga Province between latitudes 24°30' and 25°20' south and longitudes 30°05' and 32°25' east with a total catchment area of 6 437 km^2 (**Figure 6**). The Sabie River originates in the Drakensberg and drops rapidly from the escarpment into the lowveld. The Sabie River is the only river system that flows into the Kruger National Park remaining unregulated and perennial, and the only major river system in South Africa which has not yet been impounded (Bruwer 1991). The Sand and Marite Rivers are the major tributaries of the Sabie River (**Figure 6**). Due to its pristine condition, the Sabie River has been identified as perhaps the most important river for nature conservation in South Africa (Moore & Chutter 1988). Its biota is apparently undisturbed and, at the moment, its waters theoretically unpolluted (Chunnett, Fourie & Partners 1990).

The main geological units underlying the catchment are; Meihardskraal granite, Sand River gnies, Suurberg, Drakensberg, Lebombo, Transvaal, Rooiberg and Griqualand west (**Table 5**). The major soil types derived from the geological units are Glenrosa, Hutton and Shortland (DEA 1994, **Table 4**).

The Sabie River catchment receives an mean annual rainfall of 833 mm, resulting in a mean annual runoff of 134 x 10^9 m^3/km^2 (DEA 1994). The population density of the catchment is 135 people/km^2 which is the highest of all the catchments studied. The natural vegetation in the catchment consist Pure grassveld, Inland tropical forest and Tropical bush and savanna (Acocks 1988). The upper catchment has been severely altered by extensive exotic cultures of pine and eucalyptus forests. Afforestation started before the end of the last century in order to supply the eastern Transvaal mines with timber supports. The present afforested area covers 71 100 ha which is 16% of the total catchment area (Chunnett, Fourie & Partners 1990) and irrigated crops consist 11 300 ha (1,8% of the catchment, **Table 2**). The principal crops under irrigation are bananas, avocados, citrus, paw paws and vegetables (**Table 2**). It is expected that, by the year 2010 the amount of irrigation will have more than doubled to more than 23 000 ha. Dry-land farming covered over 11 570 ha (1,8%) of the catchment in 1990 (Chunnett, Fourie & Partners 1990).

The major industrial development in the catchment are confined to wood processing factories and saw mills in the Sabie and Graskop areas. Smaller service industries are concentrated around Mkuhlu, Thulamahaxi, Bosbokrand, Sabie and Graskop. Mining activity has declined, leaving only five active gold mines in the catchment (**Table 2**).

The only site utilized in this study was at a weir (WEIR) within the Kruger National Park, reflecting the effects of all the major land uses in the catchment (**Figure 6**).

Site 1: Sabie Weir close to border of the Kruger National Park.

2.3 The Crocodile River

The Crocodile River is the largest tributary of the Komati River and joins the Komati River shortly before it enters Moçambique (**Figure 7**). The Crocodile River originates in the highveld near Dullstroom and has several main tributaries namely the Elands, Wit, Kaap and Nels Rivers. The catchment of the Crocodile River covers an area of *ca* 10 440 km^2 (**Table 2**). Some 20% of the catchment lies within the southern sector of the Kruger National Park (**Figure 7**) and acts as the southern boundary of the Kruger National Park.

The Crocodile River is a regulated river with the Kwena Dam having been completed in 1984. This dam was built to sustain the large area of irrigation that takes place in the middle and lower reaches of the river.

The main geological units underlying the catchment are: Barberton, Murchison, Giyani, Beit bridge, Meihardskraal granite, Sand river gnies, Suurberg, Drakensberg, Lebombo, Transvaal, Rooiberg and Griqualand west (**Table 5**). The major soil types derived from the geological units are Glenrosa, Hutton, Shortland and Valsriver (DEA 1994, **Table 4**).

The catchment supports some 95 000 ha of irrigated agricultural crops which is the largest irrigation area in the Republic of South Africa (**Table 3**). The most important crops being sugarcane (21 000 ha), citrus (20 000 ha), bananas (7 500 ha) and tobacco (5 500 ha; DWAF 1995b). Most of the irrigated agriculture takes place in the lowveld (lower Crocodile River). Dry-land farming covered over 290 000 ha (27.8%) of the catchment in 1987 (Strydom *et al.* 1987). Exotic forestry comprises the largest intensively managed landuse in the catchment, most of it occurring in the north east (**Table 2**). Exotic plantations cover some 17 22 km^2 (16.5% of the catchment).

The lowveld has currently the fastest economic growth in the Republic of South Africa. This is specifically evident in industry. The exploitation of the natural development potential within the Crocodile River Catchment will undoubtedly put pressure on the environment (Ligthelm & Wilsenach 1991). Industrial and commercial activity in the area has been focused on the major town of Nelspruit, while limited activity occurs at Barberton, White River, Waterval Boven, Hectorspruit, Malelane,

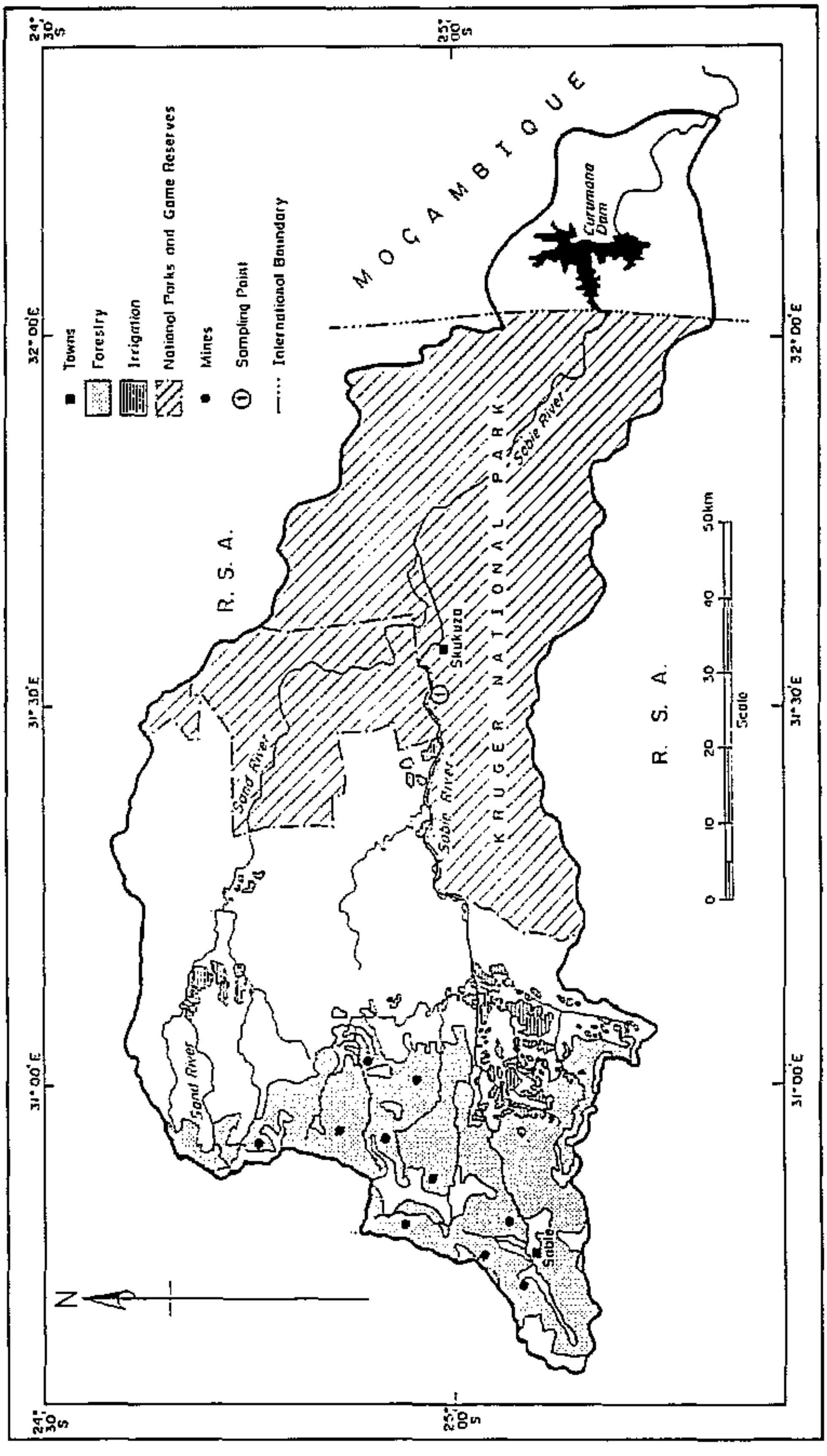


Figure 6: The Sabie River catchment and sampling sites.

Komatipoort, Kaapmuiden and Kanyamazane. There are 18 major industries within the Crocodile River Catchment which are directly dependant on either the forestry or agricultural resources produced in the catchment viz. a pulp and paper mill, a chipboard factory, saw mills and timber sorting; fruit handling and processing, fruit juice processing and canning, and a sugar refinery. Minerals mined outside the catchment are processed at three factories within the catchment viz. manganese, chrome and iron. The Kaap River area around Nelspruit once boasted a thriving gold mining community. Today only seven active mines exist in this area. Less economic minerals such as asbestos, magnesite and talc are still mined within this area.

The sites used in this study are indicated in **Figure 7** and are listed below:

Site 1 : Montrose Falls, weir above Montrose falls in Crocodile River that receives water released from the Kwena Dam

Site 2 : Rivulets, fast flowing narrow reach of river, below the escarpment and below confluence of Crocodile and Elands Rivers. Steep incised banks with thick well established marginal vegetation and overhanging trees.

Site 3 : Crocodile River Motel, fast flowing narrow reach of river. Steep incised banks with thick well established marginal vegetation and overhanging trees.

Site 4 : Mataffin Weir above Nelspruit and below confluence with Gladdespruit

Site 5 : Angling Club, adjacent to industrial area of Nelspruit. Steep incised banks with thick well established marginal vegetation and overhanging trees.

Site 6 : Lions Club, below Nelspruit and below confluence of Crocodile and Bestersspruit Rivers. Steep incised banks with thick well established marginal vegetation

*Site 7 : Kaapmuiden, below confluence of Kaap and Crocodile River.

Site 8 : Riverside Weir, below Malelane. Well established marginal vegetation and bed rock.

Site 9 : Tenbosch Weir, above the confluence of the Komati and Crocodile Rivers. Bed rock and riffles. Sand banks upstream of weir and reeds the dominant marginal vegetation.

*No fish of a suitable size were collected.

2.4 The Luvuvhu River

The Luvuvhu River is situated in the Northern Province between latitudes 22°25' and 23°20' south, and longitudes 29°50' and 31°20' east (**Figure 8**). The Luvuvhu River catchment is 3 568 km^2 of which 24 % is in the Kruger National Park (HKS 1990, **Table 2**). The river rises immediately east

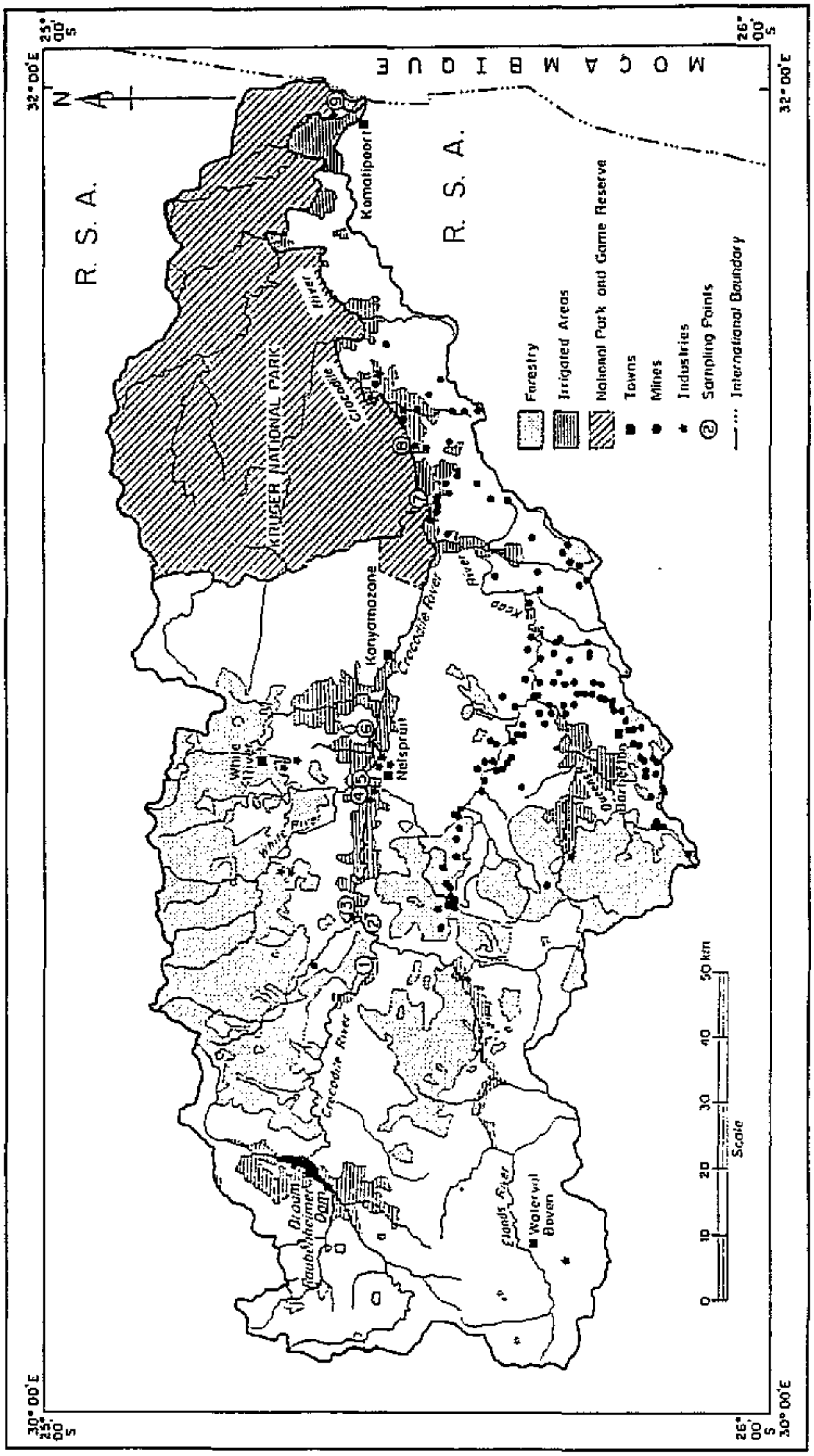


Figure 7 : The Crocodile River catchment and sampling sites

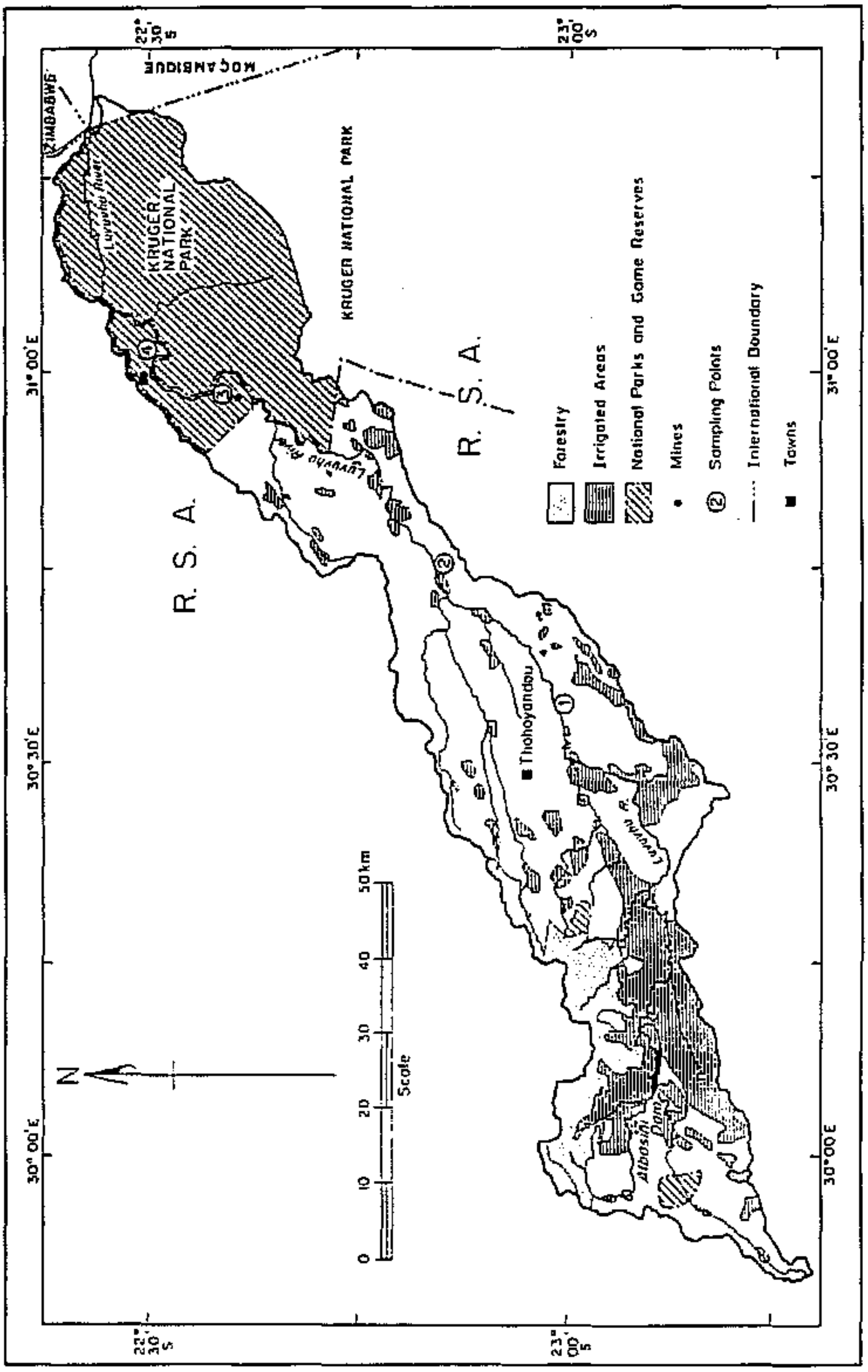


Figure 8 : The Luvuvhu River catchment and sampling sites

of Louis Trichardt on the southern slopes of the Soutpansberg mountain range flowing eastward to merge with the Limpopo River.

The geology in the catchment consist a variety of geological units with the most important ones being: Barberton, Murchison, Giyani, Beit bridge, Suurberg, Drakensberg, Lebombo, Waterberg, Soutpansberg, Orange river alluvium, Sand, Calcrete, Meinhardskraal granite and Sand river gnies (**Table 5**). The diversity in geological units is the origin of the four main soil types being found in the catchment *viz*. Glenrosa, Hutton, Mispah and Shortland (DEA 1994, **Table 4**).

The mean annual rainfall for the catchment is 731 mm of which most is received during the summer months with the highest rainfall occurring on the steep slopes of the Soutpansberg. The mean annual runoff from the catchment is 89 x 10^9 m^3/km^2 with an uneven distribution varying from 3% of the mean annual precipitation in the dry regions to 38% in the higher rainfall areas (Breen *et al.* 1994).

The total basin population was 270 500 in 1985 and increased to 302 923 in 1991, of which a large proportion is dependent on the river for water. Thoyandou, Louis Trichardt and Malamulele are supplied with water from the basin. Currently the population density is 85 people/km^2. The natural vegetation of the area consist Inland tropical forest and Tropical bush and savanna (Acocks 1988).

Forestry, covering an area of 14 600 ha (4.2%), reduces runoff from the upper reaches and affects water quality through exposure of the underlying geology. The crops produced on the 9 900 ha (2.8%) under irrigation are mainly subtropical fruits, including bananas, mangoes, litchis and papaws (**Table 3**). Agriven has established a number of irrigation schemes that include coffee and tea plantations, summer crops (cotton, tobacco, maize), winter wheat and vegetables. There are many semi-subsistence (semi-intensive) agricultural areas along the Luvuvhu River as well as substantial livestock populations, including cattle, sheep and goats (**Table 3**).

The development of industries in the catchment is in the early stages. The present industries are in Thoyandou and Louis Trichardt (**Table 2**). Existing industries include a roller mill, a brewery, knitwear steel works, saw mills, motor engineering works and many small industries (HKS 1990). The extent of the minerals found in the catchment include coal, copper, cobalt, corindium, phosphate and vermiculites. Most of the mines are closed but ISCOR is at present mining coal in the catchment. GENCOR has shown interest in acquiring rights to copper and cobalt in the Makuya Nature Reserve which is now incorporated within the greater Kruger National Park.

Four study sites were selected (**Figure 8**) in collaboration with local scientists to represent water effected by most of the land uses. Site one (FARM) is situated upstream of Thoyandou in an area with intensive commercial agriculture. The second site (SETTLMNT) was selected downstream of site one in a rural area with some subsistence farming. Surface runoff from settlements could impact on this site. Site three (MKYAUPST) and four (MKYADNST) are both situated in Makuya National Park where the Luvuvhu river serves as the border with Kruger National Park. At these sites the effects of all upstream landuse practices are represented (MKYAUPST & MKYADNST) as well as possible effects from mining activities (MKYADNST) in Makuya National Park. These sites are listed below.

Site 1 : Intensive irrigation area on Luvuvhu River upstream of Thohoyandou. Broad slow flowing with incised steep banks and well established marginal vegetation

Site 2 : Rural area with subsistence agriculture. Broad river with sandy-pebbly bed and narrow band of reeds

Site 3 : Makuya National Park site on Luvuvhu River close to start of National Park and upstream of mining activity.

Site 4 : Makuya National Park downstream of mining area. Pebbly river bed and well established marginal vegetation

2.5 The Olifants River

The Olifants River catchment is the second largest in the old Transvaal and is situated between latitudes 23°50' and 26°10' south and longitudes 28°30' and 32°00' east (**Figure 9**) and drains an area of about 54 500 km^2 (**Table 2**). The river rises near Cullinan, about 45 km east of Pretoria, on the Highveld. The river flows eastward joining up with several major tributaries (Steelpoort, Elands, Wilge, Little Olifants, Klasserie and Timbavati) and then Letaba River before flowing into the Massingir Dam in Moçambique and ultimately the Limpopo River (**Figure 9**). The catchment can be divided in four main topographical zones *viz*. the Highveld (1200 m - 1800 m above sea level), the Springbok flats (Middleveld, 900 m - 1200 m above sea level), the Drakensberg escarpment zone and the Lowveld (300 m - 900 m above sea level, SRK 1991).

Dams in the Olifants River catchment play an important role in supply water at a high level of assurance. The largest dam is the Loskop dam (capacity 348 Mm^3), followed by Rhenosterkop (205 Mm^3), MoKgomo Matlata (105 Mm^3) and Witbank (104 Mm^3).The flow in the Olifants River in the Kruger National Park is directly related to the operation of the Phalaborwa Barrage. A compensation flow of 1.5 m^3/s is released into the Kruger National Park. This compensation flow is maintained in the winter by water released from the Blyderiverspoort Dam.

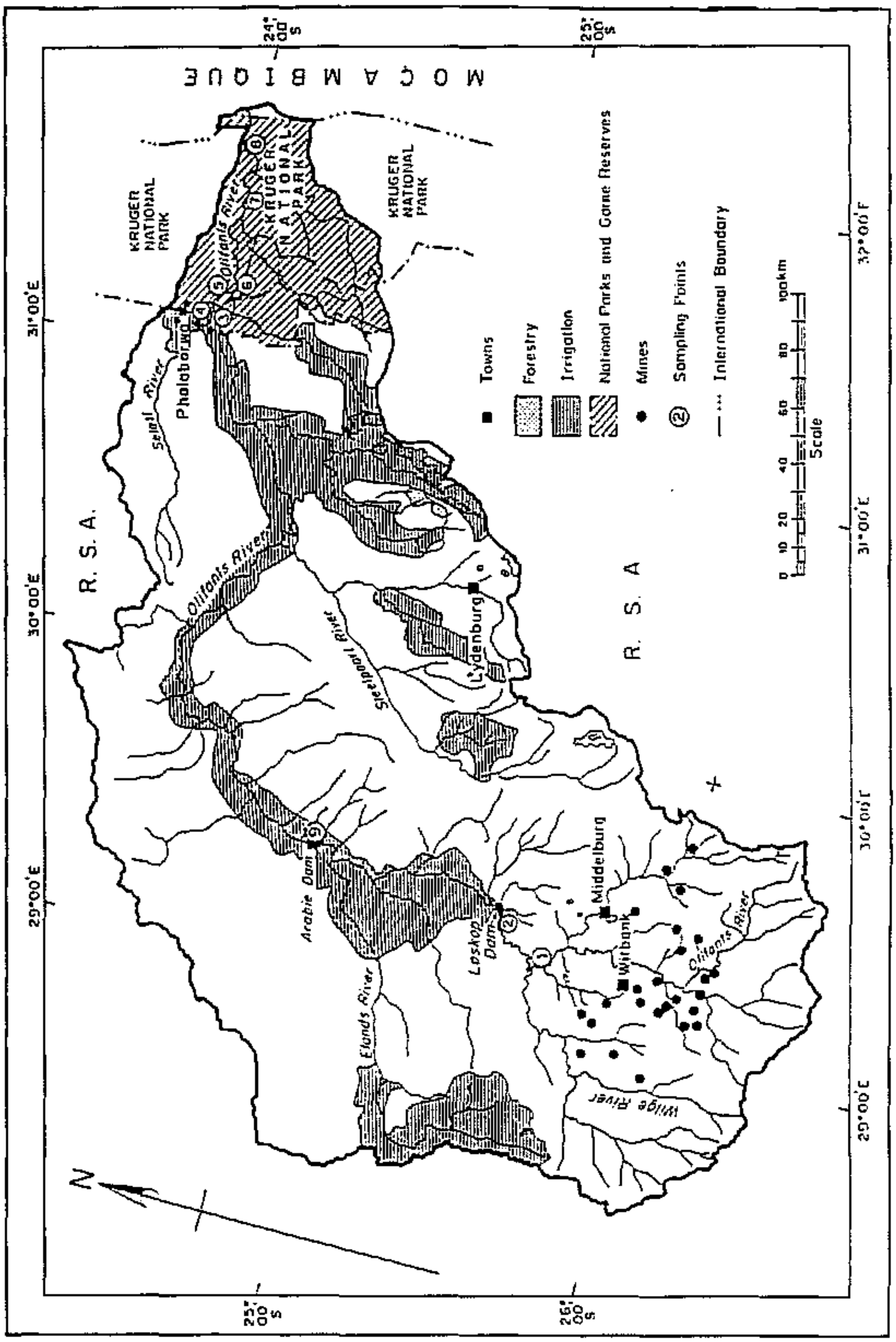


Figure 9 : The Olifants River catchment and sampling sites

The catchment consist a wide variety of geological units *viz*. Barberton, Murchison, Giyani, Beit bridge, Bushveld complex, Ecca, Meinhardskraal granite, Sand river gnies, Rustenburg, Lebowa, Rashoop, Suurberg, Drakensberg, Lebombo, Transvaal, Rooiberg and Griqualand west (**Table 5**). These geological units form the basis of the soil types represented in the catchment being Arcadia, Glenrosa, Hutton, Mispah and Shortland (DEA 1994, **Table 4**).

The climate of the catchment is warm to hot sub-tropical, with seasonal rainfall occurring predominantly in the summer months (October to March). Rainfall generally varies with altitude with maximum rainfall falling in the higher altitudes. The mean annual rainfall for the catchment is 675 mm resulting in mean annual runoff of 47×10^9 m^3/km^2, which is the lowest of all the catchments studied.

The population of the Olifants River catchment was about 2.5×10^6 in 1990 of which about two thirds live in rural or semi-urban (settlement) conditions. The largest urban concentrations are in Middelburg and Witbank. Currently the population density is 84.6 people/km^2. The natural vegetation in the catchment consist False grassveld, Pure grassveld, Inland tropical forest and Tropical bush and savanna (Acocks 1988). There are three vegetation biomes in the Olifants River catchment namely the grassland, savanna and forest biomes (Theron *et al*. 1991). The grassland biome is mainly the Highveld. The savanna biome comprises the greater part of the Springbok Flats and the Lowveld, as well as the north-east part of the escarpment. The forest biome covers a small portion of the catchment and is more or less centred around Mica in the Lowveld.

At present *ca*. 103 000 ha (2%) of the catchment is irrigated and a further 1.2×10^6 ha used for dry land agriculture. Irrigated crops are dominated by maize. Other crops include tobacco, bananas, citrus, grain sorghum, cotton, deciduous and sub-tropical fruits (**Table 3**). Exotic afforestation covering *ca*. 72 000 ha (1%) occurs in the south eastern section near Pilgrims Rest (Theron *et al*. 1991). Many of the country's coal mines, Eskom power stations, steel industries and large irrigation schemes (below Loskop Dam) are situated in this area (Theron *et al*. 1990) (**Table 2**). In Olifants River catchment considerable mineral deposits are found. A total of 216 active mines exist which include coal, gold, chrome, magnesite, vanadium, platinum, iron, lime, mica, tin, copper, phosphate and fertilizer. The major concentrations of mining activities are at Witbank and Middelburg (coal), Steelpoort (Fe, Cr, Mn and Mg) and Phalaborwa (phosphate and copper, Breen *et al*. 1994). More than 50 of the mines are coal mines. The 45 mines around Phalaborwa (10 closed and 6 still to be commissioned) use some 84% of the water supplied by the Phalaborwa Water Board.

The sampling sites were selected to represent the major industries in the catchment. Site one at the

Klipspruit confluence downstream of the Witbank-Middelburg complex (KLIPSPRT) represents the effects of coal mining, large industries and power generation on the river. Arabie Dam (ARABIE) reflects the extensive agricultural practices downstream of Loskop dam with the site at Loskop Dam (LOSKOP) being representative of the agriculture and industrial development upstream of the dam. The Selati River (SELATI) draining the mining complex at Phalaborwa was sampled as well as sites before (PRESELAT) and after (PSTSELAT) its confluence with the Olifants river. A few sites in Kruger National Park that were sampled viz. Mamba Weir (MAMBA_WR) at the western boundary of the Park, Vyeboom (VYEBOOM) halfway through the park and Baluli (BALULI) downstream before the confluence with the Letaba River. These sites are listed below.

Site 1 : Confluence of Olifants and Klipspruit Rivers. The Klipspruit drains the Witbank industrial area which is impacted by coal mining and heavy metal industries.

Site 2 : Loskop Dam which is below the confluence of the Wilge and Olifants Rivers. This site represents the agricultural and industrial development upstream of the dam.

Site 3 : Olifants River upstream of the Selati River confluence and below Phalaborwa barrage. This site is pre the impacts of the Phalaborwa complex mining.

Site 4 : Selati River which runs through the mining area of Phalaborwa.

Site 5 : Olifants River Weir below confluence with Selati River

Site 6 : Mamba Weir on Olifants River within the Kruger National Park (western boundary)

Site 7 : Vyeboom site roughly halfway through the Kruger National Park.

Site 8 : Baluli site within the Kruger National Park before the confluence with the Letaba River.

Site 9 : Arabie Dam at confluence with Elands River.

2.6 The Berg River

The Berg River lies in the Western Cape province between latitudes 32°45' and 33°50' south, and longitudes 18°15' and 18°55' east (**Figure 10**). It rises in the Jonkershoek and Franschhoek mountains from where it flows north to drain into the sea at St Helena Bay with a total length of approximately 270 km and a catchment of some 9 000 km^2 (**Table 2; Figure 10**).

The river has steep gradients in the upper reaches which flatten out in the Paarl-Wellington area. In addition the main river channel meanders considerably in the lower reaches, and the river may separate into several smaller channels. Pools and backwaters are also formed in the lower reaches suggesting

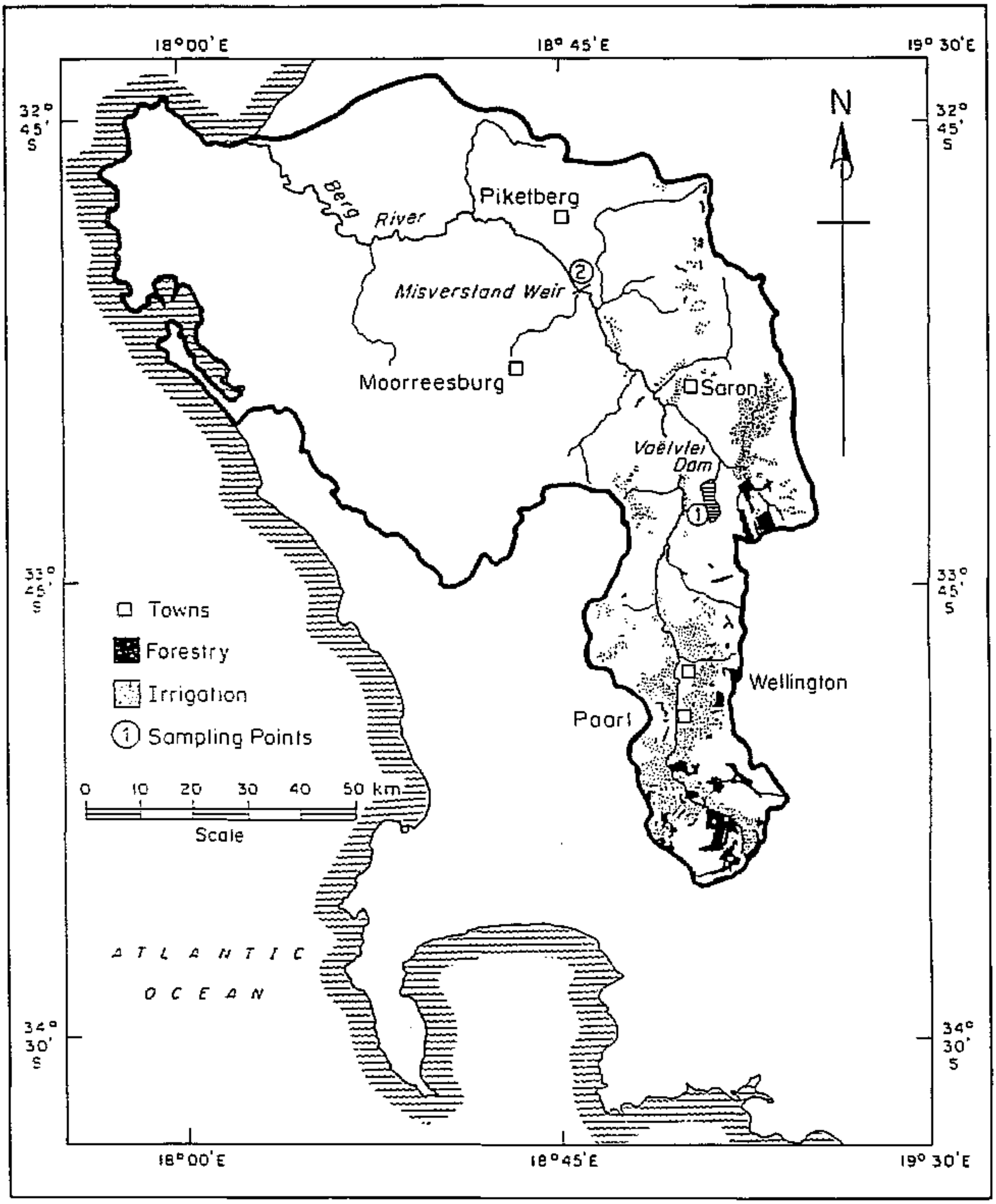


Figure 10 : The Berg River catchment and sampling sites

that it is an old river system. The river is regulated by a large weir - the Misverstand Weir. An off channel storage dam the Voëlvlei Dam supplies water for potable purposes.

The main geological groups in the catchment include Alluvium, Sand, Calcrete, Cape granite, Malmesbury, Kango, Gariep and Table mountain (**Table 5**). The sandstone weather slowly to acidic soils consisting Fernwood, Rock and Swartland (DEA 1994, **Table 4**). Soil depth is shallow on the steeper slopes, but thickens down into the valleys. Soils derived from the Malmesbury shales are usually sandy and gravely loams of shallow depth (Bath 1992).

The Berg River catchment falls within the winter rainfall area of the south-western Cape, and some 80 percent of the rain falls in the six months from April to September. The rainfall is primarily cyclonic in nature, and is associated with the regular winter frontal systems which pass over the south-western Cape. The mountain ranges force the air masses upward resulting in a reliable rainfall in the high lying areas of up to 3 000 mm per year. This decreases to 400 - 500 mm in the flatter parts of the catchment and may be as low as 250 mm with the mean annual rainfall for the catchment being 524 mm. Runoff from the catchment is relatively high with a mean of 116 x 10^9 m^3/km^2 for the catchment. In summer high temperatures associated with low rainfall and strong south-easterly winds increase the evaporation rate in the exposed areas of the catchment, as is evident from the annual evaporation of 2 711 mm at Voëlvlei Dam.

The Berg River catchment lies in one of the most developed areas of the country, and most of the catchment is subjected to some form of human activity. The population of the magisterial districts falling within the Berg River catchment amounts to some 347 000 people with a population density of 37 people/km^2. The original vegetation in the catchment has almost entirely been replaced by urban or agricultural activity. Vestiges of the natural Fynbos biota only exist in the higher lying areas where steep slopes are not conducive to human development. The original biota of the catchment consisted Coastal macchia, Coastal renosterveld, Macchia and West coast strandveld (Acocks 1988).

Agriculturally the soils are considered to be poor in phosphorus and nitrogen, fairly acid, and tend to cake when wet (Bath 1992). These soils are suited to grain production, and the Malmesbury shale areas are predominantly put over to winter wheat production. The nutrient poor and soils are only suitable for the cultivation of vines and fruit trees after the application of large quantities of fertiliser. The major crops grown are dryland wheat and irrigated grapes (**Table 3**). At present the total area under irrigation is only 7 500 ha. The afforested areas occur primarily in the high lying areas of the catchment. The major industries in the Berg River catchment are food processing (fruit, foods, canning, dairy, fish canning), breweries, wineries, textiles (clothing and leather), chemicals, cement, glass and refineries. There are no mines in the catchment (**Table 2**).

Two sampling sites were selected in the Berg River catchment viz. Voëlvlei Dam and Misverstand Weir.

Site 1: Voëlvlei Dam is situated in the foothills of the Voëlvlei Mountains approximately 6.8 km south of the town of Gouda in the Western Cape province (**Figure 10**). Originally this dam was a natural marsh with approximate dimensions of 6.4 by 1.6 km. The water supply to the marsh was increased in 1952 by erecting a weir a few kilometres above Gouda in the Little Berg River. Water from this river was diverted to Voëlvlei in a concrete canal. During the late sixties it was agreed to increase the water provision ability of the Voëlvlei and thus to be able to supply the anticipated growing demands of the area. Erection and completion of earth embankments at the northern and southern sides of Voëlvlei in 1971 resulted in an increase of Voëlvlei dam from 44.648 x 10^6 m^3 to 159.532 x 10^6 m^3 (Greichus *et al.* 1977).

Site 2: Misverstand weir was built to improve the water supply to towns in the Saldanha Bay/Vredenburg area (**Figure 10**). This supply scheme involved the construction of a weir at Misverstand, some two km upstream of the main Malmesbury-Piketberg road. This impoundment was linked to the Withoogte water treatment works via a 12.5 km pipeline. The Misverstand Weir has a capacity of 6 x 10^6 m^3 and a yield of 30 x 10^6 $m^3.yr^{-1}$.

3. MATERIAL AND METHODS

Researchers who were active in each catchment were used to identified sampling sites that were close to point and/or diffuse sources of agricultural and industrial pollution for investigation. These sites should reflect the levels of pesticides and heavy metals that could potentially enter the Kruger National Park and the lower Berg River.

In **Table 6** the sampling trips sponsored by this study (1992 and 1993); as well as previous trips' data that was also used to supplement this study are indicated. This table also indicates the other types of data collected such as water quality, fish, metal and pesticide residues in fish tissues.

3.1 Water Quality

Physical and chemical water quality variables such as temperature, pH, conductivity, turbidity and dissolved oxygen were determined at each site using field instruments (WTW OXY 92 and Hanna Hand Held turbidity probes).

Grab water samples were collected from each site and on each sampling trip (**Table 6**) for water quality determination. The water samples were collected in sterile (acid washed) 2ℓ plastic bottles for macro-constituent determination (nutrients, major cation and anions). Glass 500 mℓ bottles were used to collect water for metal determination. In these glass bottles mercury chloride was used as a preservative. The sample bottles were placed on ice in a portable fridge and transported to the laboratory for analysis. The water samples were filtered and consequently the results indicate the soluble fraction of the variables determined. The water samples were analyzed according to Standard Methods (Standard Methods 1989).

Pesticides levels were not monitored for in the river water as experience has shown that this exercise is a not cost effective and is time consuming as the pesticide levels in the river are normally below the levels of detection.

3.2 Fish Sample Collection, Preservation and Detection of Metals and Pesticides

Fish were collected in all rivers according the schedule indicated in **Table 6**. Standard fish collection techniques, such as gill (stretched mesh sizes ranging from 50 mm to 90 mm) and seine nets (stretched mesh size 20 mm), were used. The fish were caught, identified and only larger species were selected (if possible) for this study due to large weight of tissue required for metal and pesticide determination. The following parameters measured on each of the selected fish species:

(i) **Species identification** (Jubb 1967, Le Roux and Steyn 1968. Pienaar 1978)

(ii) **Standard length** (mm)

(iii) **Mass** (g)

(iv) **Gender** (male. female or juvenile)

(v) **Gonad development index** (G.I. index using Olatunde's 1978, 6 point gonadotrophic index, Table 7). Immature fish are represented by -1, well developed gonads by IV and Spent fish represented by VI.

(vi) **Stomach content analysis**. A representative sample of the species sampled with distinct stomachs was collected and preserved in 5% formalin for laboratory analysis. The contents were identified and the percentage composition determined under a dissecting microscope. For species of fish with no distinct stomachs the foregut was collected, preserved, the contents was identified and the percentage composition determined under a dissecting microscope.

(vii) Age indicators such as scales and spines (dorsal and pectoral) were collected from the fish species that tissue sample were collected from. The scales were washed in soapy water and mounted between two a glass slide. The growth rings were read on a microfiche projector. Thin sections of the spines cut using a hacksaw blade and further reduced in size using sand paper. The thin sections were read under a compound microscope in the laboratory.

(viii) **Bioconcentration factor** (BCF) reflects the difference in concentration of the variable in the water and the tissue was calculated using the formula of Wiener and Giesy (1979):

$$BCF = \frac{Co}{Cw}$$

Where: Co = Wet weight concentration of the variable in the fish tissue

Cw = Total average concentration of the variable in water

(ix) **Pesticide analysis** was undertaken if sufficient tissue was available form each species of fish caught, the following tissues and organs were dissected out for : flesh (muscle), liver, fat, testes, ovaries, gills and gut. A minimum of 15 g of sample is required for pesticide analysis. These samples were kept in a frozen state until analysis was undertaken. Organochlorine, organophosphorus, carbamates, pyrethroids and triazine pesticide residues in the fish tissue samples were analyzed in duplicate using gas chromatographic methods (National Institute of Public Health and Environmental Protection (RIVM), Netherlands, June 1988 a to c, Krause

1980, **Table 8**). Recoveries were done by adding known amounts of analytical standards to portions of samples submitted and analysing these concurrently with the samples.

Table 6: Dates of sampling trips and data collected that was used in this study.

Rivers and dates	Water quality	Metals	Pesticides	Fish biology
Letaba				
February 1990	✓	✓	✓	✓
May 1990	✓	✓	✓	✓
August 1990	✓	✓	✓	✓
November 1990	✓	✓	✓	✓
February 1991	✓	✓	✓	✓
May 1991	✓	✓	✓	✓
August 1991	✓	✓	✓	✓
November 1991	✓	✓	✓	✓
May 1993	✓	✓	✓	✓
June 1992	✓	✓	✓	✓
Sabie				
May 1992	✓	✓	✓	✓
June 1993	✓	✓	✓	✓
Crocodile				
June 1989	✓	✓	✓	✓
September 1989	✓	✓	✓	✓
January 1990	✓	✓	✓	✓
March 1990	✓	✓	✓	✓
June 1990	✓	✓	✓	✓
October 1990	✓	✓	✓	✓
January 1991	✓	✓	✓	✓
March 1991	✓	✓	✓	✓
September 1991	✓	✓	✓	✓
September 1992	✓	✓	✓	✓
Luvuvhu				
August 1992	✓	✓	✓	✓
July 1993	✓	✓	✓	✓
Olifants				
June 1992	✓	✓	✓	✓
February 1993	✓	✓	✓	✓
June 1993	✓	✓	✓	✓
November 1993	✓	✓	✓	✓
Berg				
October 1992	✓	✓	✓	✓
October 1993	✓	✓	✓	✓

Table 7: Criteria for the classification of fish gonad development adapted from Kesteven and Nikolsky (Olatunde 1978).

Gonad Index Stage	Characteristic
0. Inactive (I)	Small gonads, close to the vertebral column. Gonads transparent and grey.
1. Inactive-Active (IA)	Testes and Ovaries translucent, grey-red. Single eggs just visible to the naked eye. Gonads extending most of the length of the ventral cavity.
2. Active (A)	Eggs visible to the naked eye. Gonads reddish with blood capillaries, filling 1/3-1/2 of the ventral cavity.
3. Active-Ripe (AR)	Ovaries orange-red (Not *C. gariepinus* -gonads remain grey). Testes white with red blood vessels. No milt-drops appear under pressure. Eggs opaque.
4. Ripe (R)	Sexual products mature. Testes exude milt when pressure exerted. Eggs spherical.
5. Ripe-Running (RR)	Eggs and milt running with slight pressure.
6. Spent (S)	Gonads have the appearance of deflated sacs, reddish colour. Occasional residual eggs and some milt.

The analytical procedure for pesticide detection used was as follows:

Extraction: Samples were extracted with a mixed solvent (Ethyl acetate:hexane) and sonicated for 2 minutes (in order to break the cell walls).

Clean up: Pesticides are separated from fat fraction with liquid-liquid partitioning. Further clean up was done by solid phase extraction on florisil cartridges. During this step the organochlorines were also separated from the organophosphates.

Detection: Organochlorines were detected by ECD. Organophosphates were detected by NPD detectors.

Separation was done on three capillary systems of different polarity, namely DB1 (NON polar), OV1701 (Medium polar), OV210 (very polar). The reason being that certain peaks, which overlap in one system is separated on another.

The results were also quantified on three systems to pick up any wrong results from co-eluting peaks.

Positive results were as far as possible confirmed by GC-MS. The GC-MS system is about 100 times less sensitive than the ECD detector and 10 times less sensitive than the NPD detector. Therefore it is not always easy to confirm results at very low levels.

Triazine residues may be determined by HPLC, which is expensive and long-winded, or GC, by which it is less time consuming but still specific.

Various combinations of the following pesticides were analyzed for and, under the conditions of the test employed, the lowest limits of detection were as indicated in **Table 8**.

The pesticide levels are be expressed as mg/kg on a natural (wet weight) basis.

The value that is used for the pesticide analysis is not a true detection limit (**Table 8**). This is the lowest level whereby a reliable calculation can be undertaken or level of reliable calculation. A computer programme, with the assistance of a standard curve calculates (indicates) when a value differs significantly from zero.

(x) **Metals** to be determined in the fish tissue were selected depending on the land usage and consequent expected variables of concern within each catchment studied. Depending on the number and size of each species of fish caught, the following tissues and organs were dissected out for **metal analysis**: flesh (muscle), liver, fat, testes, ovaries, gills and gut. A minimum of 10 g of sample is required for metal analysis. These samples were kept in a frozen state until analysis was undertaken.

The metals were analyzed using the method prescribed by Watling (1981). All tissues were treated in the same way i.e fat, testes, ovaries, flesh and liver. The simplified method used was as follows:

Sample dissolution

The wet sample is transferred to a clean 200 mℓ Erlenmeyer flask and can be either dried in an oven at 95 °C for 24 hours, or freeze-dried at -60 °C at a pressure of less than 100 mm mercury for 24 hours. In either of these methods there is no loss of study elements.

The dry sample was then weighed.

This method is used for preparing samples prior to copper, lead, zinc, iron, manganese, cobalt, nickel, cadmium and chromium analysis (Watling 1981).

An amount of 10 mℓ of concentrated nitric acid was added to the sample.

The sample was digested (evaporated) to dryness on a hot plate. If the residue remains black or dark in colour (not all biological material has been oxidised) then add more nitric acid plus 1 mℓ of distilled water and digest again. Continue digesting until the residue takes on a light straw colour.

Add 10 mℓ of 10% nitric acid and dissolve the residue with gentle warming.

Using flame atomic absorbtion spectrophotometry (FAAS) measure the concentration of each respective element.

This method is used for preparing samples prior to mecury analysis. Add 20 mℓ concentrated nitric acid to the sample and leave the mixture for 24 hours. After this time evaporate the sample to dryness on a hotplate at 120 °C. This step is repeated until the residue starts turning white. When dry add 20 mℓ of a 4:1 mixture of nitric acid and perchloric acids. Evaporate the mixture to near dryness and if the supernatant solution is either clear or slightly yellow fume the sample to dryness. If the supernatant liquid is orange, add a further aliquot of nitric:perchloric acid and fume the sample to dryness. Allow the dry residue to cool and add 10 mℓ 105 nitric acid. Allow this mixture to stand for 2 hours with occasional shaking to bring the residue into suspension, then transfer the whole sample to a 20 mℓ polytop vial and allow the residue to settle. If necessary the supernatant liquid can be filtered or decanted into a separate vial to await analysis.

Accurately weigh 2-3 g wet sample into 150 mℓ Erlenmeyer flask fitted with a bubble stopper and add 25 mℓ 6% weight/v potassium permanganate and 1 mℓ concentrated sulphuric acid. Heat the mixture in a water bath at 55°C for 2 hours or until the tissue dissolves or the potassium permanganate is discoloured. Then add 25 mℓ concentrated sulphuric acid and 20 mℓ 6% weight potassium permanganate solution and heat the mixture for a further 4 hours. Store the oxidized sample in the digestion flask to await analysis.

Immediately prior to analysis, add 5 mℓ 20% weight/v hydroxyammonium chloride solution to the flask and allow all deposited manganese dioxide to dissolve. Then transfer the solution to a 100 mℓ volumetric flask and make up the volume. to the mark. Transfer a 25 mℓ aliquot of this solution to a 200 mℓ gas wash bottle and add 50 mℓ distilled water. Then add two 20% mℓ weight/v stannous chloride solution in 20% v/v hydrochloric acid and allow the mixture to stand for 1 minute. After this time connect the gas wash-bottle in-line with the analysis apparatus and pass argon or nitrogen through the bottle for 2 minutes at a rate of 600 mℓ/min. Pass the entrained mercury through the silver wool amalgamation tube, where up to 100 ng can be quantitatively amalgamated . After 2 minutes switch

Table 8: Pesticides that were analyzed for and their levels of detection.

Pesticide group and level of detection	
Pyrethroids (0.01 mg/kg)	**Carbamates (0.1 mg/kg)**
Bioallerthrin Bioresmethrin Cyfluthrin Cypermethrin Deltamethrin Fenpropathrin Fenvalerate Phenothrin Permethrin	Aldicarb Carbofuran Carbaryl Oxamyl Methomyl Thiofanox
Organochlorines (0.001 mg/kg)	**Organophosphates (0.01 mg/kg)**
Aldrin Captafol Captan Chlordane Chlorothalonil DDT-complex * Dichlorane Dichlorfluanide Dicofon Dieldrin * Dienchlor Endosulfan Endrin Folpet α-BHC * ß-BHC δ-BHC (Lindane) * Heptachlor Hexachlorobenzene Iprodione Methoxychlor Proclonol Propachlor Propargite Quintozene Tecnazene Tolylfluanide Vinclozolin	Acephate Chlorenvinphos Chlorpyriphos Chlorpyriphos-methyl Chlorthiophos Dichlorphos Diazinon Mecapthionon Pirimiphos **Triazines (0.001 mg/kg)** Atrazine Simazine Propazine Cyanazine

Where * = 0.001 mg/kg

on the bypass system, zero the spectrometer and switch on the resistance furnace. The mercury vapour is passed into the cold vapour cell and the absorbance signal recorded. Absorbance signals are quantified by comparison with results from artificial standards (Watling 1981).

The metals in the fish tissues are expressed as mg/kg (dry weight). Under the conditions of the analysis the lowest limits of detection are indicated in **Table 9**.

The detection limits for metals were calculated by determining the differences between the three standards (at lowest concentrations) and the mean of the triplicate blanks. Two standard deviations of these three values were multiplied with the concentration of the lowest standard determined in the calibration curve and divided by the mean of the three values (**Table 9**).

Table 9: Levels of detection for tissue metal loads in fish.

Metals (for 3 g tissue)	μg/g dry weight
Al	0.83
As	2.8
Cd	0.03
Cr	0.28
Cu	0.03
Fe	0.28
Co	0.28
Pb	0.83
Mn	0.03
Ni	0.39
Zn	0.08
Hg	0.005

3.3 Prediction of Pesticide Usage

In order to determine the possible pesticide contamination of the surface waters of the catchments studied a survey was undertaken to, firstly determine the actual current landusage in each catchment, and secondly determine the actual annual pesticide usage in each catchment. It became rapidly apparent that this survey was doomed to failure for the following reasons:

- the Department of Agriculture's crop extension areas are not catchment based

- the data available on the crops grown in each catchment was "hidden in a paper chase" from one area to another

- the pesticide data used was not for public use and consequently we could not get hold of the annual records of the Cooperatives nor the manufactures. The regional extension officers of the Department of Agriculture did not have the complete picture but could verify data if it was presented to them.

The crops grown in each catchment were eventually determined by Landsat satellite images that were in the possession of CSIR. A British company (Agricultural Information Services Limited. London) undertakes annual pesticide usage surveys per crop for South African. This data base is funded by the pesticide producers in South Africa as form of market research. The 1991 pesticide usage per crop (Data base of South African pesticide usage) was purchased from this company and was used to determine the possible pesticides that could be found in the surface waters and ultimately in the fish tissues per catchment. The pesticide usage for 1991 for the catchments studied are in **Appendix E.**

3.4 Human Health Risk Assessment

Health risk assessment attempts to define the most likely health effects under given conditions of exposure. and to estimate the probability of manifestation of these effects in the exposed population The risk assessment process consists of four separate but interacting steps (US-EPA 1987; Hutzler and Boyde 1982; Cotruvo 1987; Deisler 1987), namely:

- hazard identification
- exposure assessment
- dose-response assessment
- risk characterisation

The first step in any risk assessment is the hazard identification. The goal of hazard identification is to establish whether exposure to a chemical can cause an increase in the incidence of illness (Deisler 1987). Epidemiological studies. animal experiments. historical disease statistics. short-term screening with non-mammalian systems and analogy with known hazards are the various sources used in the identification of human health hazards.

Exposure assessment measures or estimates the intensity, frequency and duration of human exposure to a contaminant under question. It is recommended that a complete assessment should deal with five major aspects of exposure. These are:

- the source of the hazard;
- exposure pathways via various media and routes;
- measured or estimated concentrations and exposure durations;
- the exposed populations; and
- an integrated exposure analysis, which combines the estimation of environmental concentrations of the health hazards with descriptions of the exposed population.

Dose-response assessment is the process of characterising the relationship between dose of a hazardous agent and incidence of an adverse effect in the exposed population. In the absence of adequate human data, well-quantified animal data is often used, particularly for chemical hazards. The method of risk calculation used is closely linked to mode of action of the health hazard. Two broad classes of chemical hazards have been defined, namely those causing toxic effects and those causing carcinogenic or similar effects.

Risk characterisation is defined as the process of calculating the incidence of the health effects under the conditions of exposure described in the exposure assessment, using the identified dose-response relationship. Risk estimates may be presented in a number of forms, eg.:-

1) Theoretical excess cancer risks (risks over background cancer incidence). Eg. if risk is 1 E-6 (or 1×10^{-6}) then a person has a one-in-a-million chance of getting cancer because of the specified chemical exposure, in addition to his/her chance of getting cancer from other causes. According to the US-EPA a risk of 1 E-6 is considered to be low.

   Risks are calculated as a function of oral slope factor and dose, namely
   $\text{Risk} = 1-e^{-(\text{oral slope factor} \times \text{lifetime average daily dose})}$

   Calculated risks should be interpreted as general indicators only.

2) Risks of chronic non-cancer health effects are evaluated using average daily doses compared to a reference dose. These risks are expressed as **hazard quotients** (H.Q.= average daily dose/reference dose).

The Hazard Index represents the sum of the Hazard Quotients for each chemical and exposure scenario to which a person may be exposed. It is used to evaluate the likelihood of non-cancer toxicity. Hazard indices of < 1.0 are considered to be associated with low risks.

In this health risk assessment, the hazard was identified as pesticides based on assumptions for exposure to pesticides through the consumption of fish (see scenarios below). Exposure assessments were carried out based on various assumptions (see scenarios below), with regard to amount of fish consumed and the numbers of times per annum fish is consumed. Risk were characterised using both geometric mean values **of 144 samples** and maximum levels detected. The **geometric mean** value determined from the pesticides in the fish tissues in this study were:

dieldrin 4.0 μg/kg;
atrazine 0.5 μg/kg;
DDT 5.0 μg/kg;
lindane 21.3 μg/kg;
DDE 14.7 μg/kg; and
endosulfan 76.5 μg/kg

The **maximum levels** detected in the fish tissues in the study were:

dieldrin 120 μg/kg;
atrazine 0.5 μg/kg;
DDT 5.0 μg/kg;
lindane 270.0 μg/kg;
DDE 100.6 μg/kg; and
endosulfan 1073.0 μg/kg

The following scenarios were used for the determination of the health risk assessment:

- consumption of fish 52 times per year (weekly)
- consumption of fish almost daily (350 times per year)
- consumption of 50 g fish per event
- consumption of 150 g fish per event

The computer programme "Risk* Assistant™"(1993) was used to conduct the risk assessment.

3.5 Statistics

The statistical analysis was undertaken using "Statistica 3.1 and 5.0" (Stat Soft. Inc 1992, 1994). The following tests were undertaken to determine the similarity of the samples:-

Kruskall Wallis analysis of variance

This test is the nonparametric equivalent to the analysis of variance (ANOVA) between groups. The Kruskall Wallis technique tests the null hypothesis that the different samples in the comparison were drawn from the same population or from populations with the same median. The Kruskall Wallis is an analysis of variance performed on ranks whereas with the conventional ANOVA the application is on the actual data.

Mann Whitney U-test

The Mann Whitney U-test is the non-parametric equivalent of the student t-test for comparing independent samples. The interpretation of the test is the same as the t-test except that the U test is based on the sums of ranks rather than means.

Regression equations were used to compare age with standard length.

4. RESULTS

The results of the water quality, fish biology, pesticide and metal fish tissue loads are included in separate sections in this chapter.

The abbreviations used in the tables of results are indicated in the pull out Appendix at the back of this report.

4.1 Water Quality

Selected physical and chemical water quality results for the rivers sampled can be seen in **Figures 11a, 11b** and **Figure 12** and are discussed below. The full data set is in **Appendix A**. The results of the water quality analyses depict the conditions at the time of the grab sample only. Interpretation of these results must be undertaken with care as for most of the rivers only two sample trips occurred (**Table 9**).

4.1.1 Temperature

Variation in temperature for the rivers sampled is a function of seasonality, geographical locality and regulation if a dam present (**Figure 11a**). The Letaba River had the highest mean temperature which can be attributed to the river having a highly regulated flow pattern as well as the high ambient temperatures of the lowveld. The outlier values from both the Letaba and Crocodile Rivers occurred in mid-summer when flows ceased due to regulation. This accounted not only for high obtained values, but also high daily variability. The Berg River impoundments that were sampled in spring had a range of 16.5 to 23.6°C.

4.1.2 Conductivity

Conductivity, being an indication of dissolved salts, indicate a definite trend with the most regulated and impacted rivers having the highest means and deviations. The Olifants River shows a very high mean value in access of 100 mS/m (**Figure 11a**). This is well correlated to the high values of contributing variables (cations and anions) from the same river. These high conductivity values are related to land usage disturbances such as mining, agricultural runoff and rural settlement activities in the catchment. The catchment with the lowest conductivity values was the Sabie (9 to 15 mS/m).

4.1.3 pH

The Berg River generally had the lowest pH values ranging between 7.2 and 8.1 which is due to the acidic nature of the soil in the western Cape (**Figure 11a**). The Olifants River indicated a standard deviation of ± 1.25 pH units. The variability of pH in the Olifants River is a result of acid mine drainage originating in the upper catchment from mining activities. The highest impacts of acid mine drainage occurs during low flow situations and can result in high metal concentrations in the rivers.

4.1.4 *Dissolved oxygen*

Due to the varying nature of oxygen content through the course of a day and the impact that impoundments have on oxygen levels only broad trends can be discussed (**Figure 11a**). The Sabie and Crocodile Rivers had the highest dissolved oxygen levels which is related to the constant flow that occurred in these two rivers during the surveys. The lack of impoundments in the Sabie and the long distance from the major dam in the Crocodile also added to the higher dissolved oxygen values in these two rivers.

4.1.5 *Nutrients (ortho-phosphate, nitrite, nitrate)*

The nutrient values in the Olifants and Luvuvhu Rivers indicate high mean values (**Figure 11b**). In the Olifants River these relatively high values are due to fertilizers used in agriculture and the mining activities around Phalaborwa. In the Luvuvhu River catchment the nutrients loads originate from agriculture runoff and sewage effluent that is returned to the river in a treated or untreated form.

4.1.6 *Sulphate*

The mean sulphate value for the Olifants River is four times that of the other rivers sampled (**Figure 11a**). These high values originate from the mining activities that occur in the upper and lower catchment.

4.1.7 *Chloride*

Chloride levels for the Olifants and Berg Rivers show the highest means with the Sabie River recording the lowest mean value (**Figure 11a**). The high mean of the Olifants River chloride levels could be the result of industries and mining activities close to sampling points. The Berg River chloride levels could be related to agricultural pesticides, soil runoff and tanning industries.

4.1.8 Metals

Selected metal results are indicated in **Figure 12**. The mean values for iron in the river sampled indicate minor variations between rivers (**Figure 12**). The Crocodile River, however, yielded a slightly higher mean value due to evident outliers. Values for lead were below the limits of detection for all samples taken. Nickel values recorded in the rivers were lower than the limits of detection for all rivers except the Luvuvhu River where a mean of 20 μg/ℓ was recorded (**Figure 12**). Mean values for zinc indicate relatively high values for the Crocodile River only, with a mean of 500 μg/ℓ and outliers in excess of 5000 μg/ℓ (**Figure 12**).

The other metals that were measured in the catchments were aluminium, arsenic, cadmium, chromium, copper, manganese and mercury (**Appendix A**). Not all these metals were analyzed for at all sites, or all the rivers, as the metals analyzed were selected according to land usage expectations. The highest aluminium levels detected were in the Klipspruit River 100 m above the confluence with the Olifants River. These high aluminium levels detected were 1.9 mg/ℓ which is considerably higher than the levels recorded in the other rivers (**Appendix A**). The highest arsenic value (15 μg/ℓ) were recorded at the Kaapmuiden site of the Crocodile River. Apart from two sites (30 μg/ℓ) in the Olifants River the levels of cobalt were below the levels of detection in the rivers monitored. Apart from the Sabie River (6 μg/ℓ) the cadmium levels recorded were below the levels of detection. The chromium values monitored were all below the levels of detection. Low levels of copper were found only in the Letaba, Luvuvhu and Olifants Rivers. Only the Meetwal in the Olifants River had a high level of copper (0.12 mg/ℓ). The manganese levels detected in the Crocodile River were generally higher than the other rivers (**Appendix A**). The Hengel (Fishing) Club had consistently higher values with a maximum manganese value of 1.2 mg/ℓ. The mercury levels recorded were generally lower than the levels of detection with traces being recorded in the Crocodile River (8 μg/ℓ maximum, **Appendix A**).

4.2 Fish Species Caught

Sixteen species of fish were caught that were large enough to have tissues dissected from for either pesticide or metal determination (**Tables 10 - 12**). Four of these species caught and analyzed are exotic species viz. common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*) largemouth bass (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieu*). As species were abundant in the catchments surveyed tissues were collected and analyzed from representative specimens.

Table 10 : **Common and scientific names of the species of fish from which tissues were taken in the Letaba, Olifants, Sabie, Luvuvhu, Crocodile and Berg Rivers in (1989 - 1993, * = exotic species).**

Common Name	Species
Large-scale Yellowfish	*Barbus marequensis*
Spotted-tailed Robber	*Brycinus imberi*
Sharptooth Catfish	*Clarias gariepinus*
Common Carp	*Cyprinus carpio**
Tigerfish	*Hydrocynus vittatus*
Silver Carp	*Hypophthalmichthys molitrix**
Purple Mudsucker	*Labeo congoro*
Plumbeous Labeo	*Labeo molybdinus*
Red-nosed Labeo	*Labeo rosae*
Silver Labeo	*Labeo ruddi*
Largemouth Bass	*Micropterus salmoides**
Smallmouth Bass	*Micropterus dolomieu**
Mozambique Tilapia	*Oreochromis mossambicus*
Butter Catfish	*Shilbe intermedius*
Brown Squeaker	*Synodontis zambezensis*
Southern Redbreasted Tilapia	*Tilapia rendalli*

Table 11: **Occurrence of the larger species of fish from which tissues were taken in the Letaba, Olifants, Sabie, Luvuvhu, Crocodile & Berg Rivers.**

Species	Sabie	Letaba	Olifants	Luvuvhu	Crocodile	Berg
B. imberi					✓	
B. marequensis	✓	✓	✓	✓	✓	
C. carpio						✓
C. gariepinus	✓	✓	✓	✓	✓	
H. molitrix			✓			
H. vittatus	✓			✓	✓	
L. congoro	✓		✓	✓	✓	
L. molybdinus		✓			✓	
L. rosae	✓	✓	✓	✓	✓	
L. ruddi	✓					
M. dolomieu						✓
M. salmoides						✓
O. mossambicus	✓	✓	✓	✓	✓	✓
S. intermedius	✓	✓	✓		✓	
S. zambezensis					✓	
T. rendalli		✓			✓	

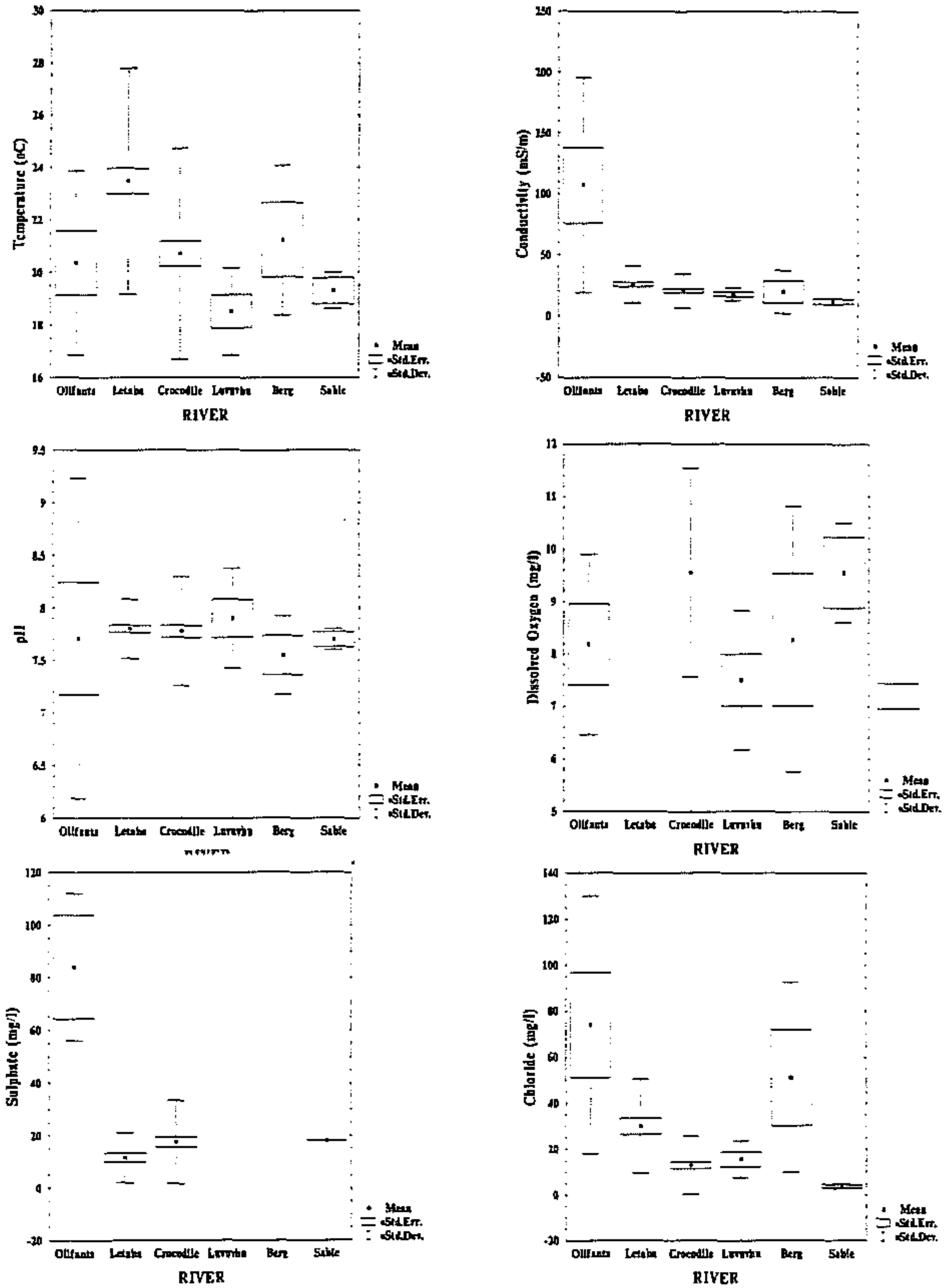


Figure 11a: **Temperature, conductivity, pH, dissolved oxygen, sulphate and chloride for all rivers sampled.**

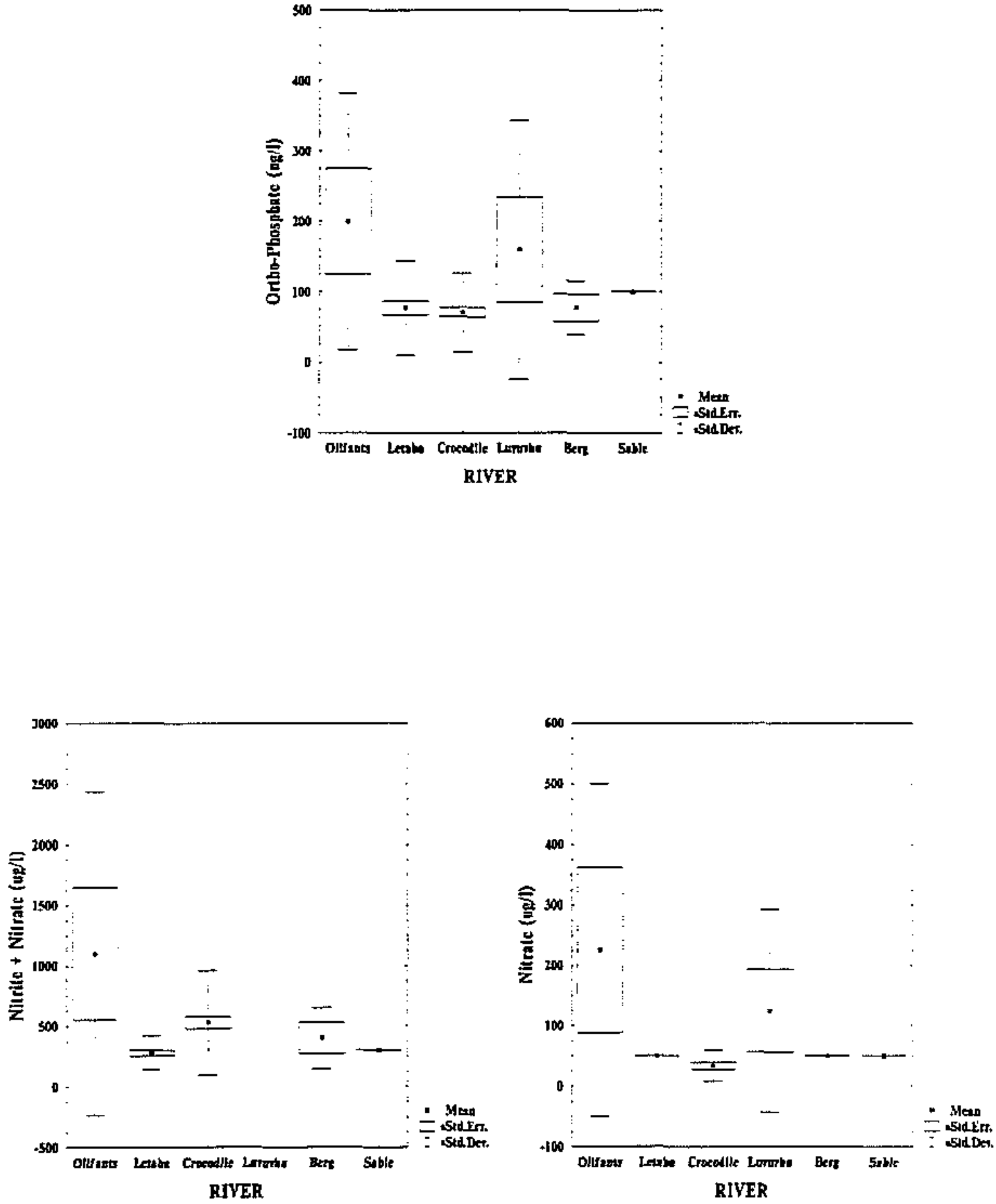
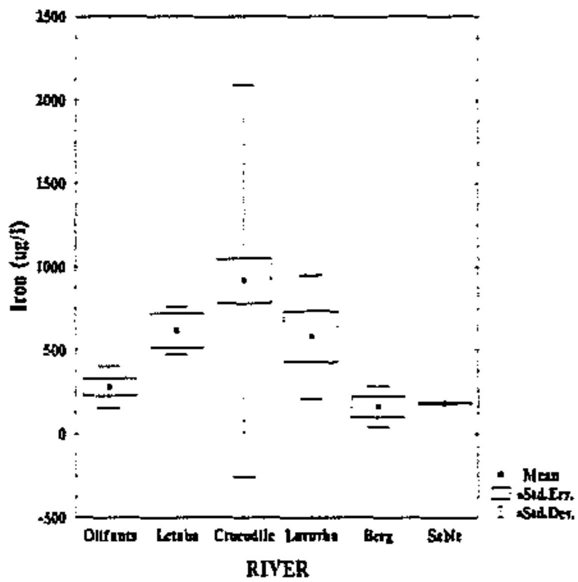
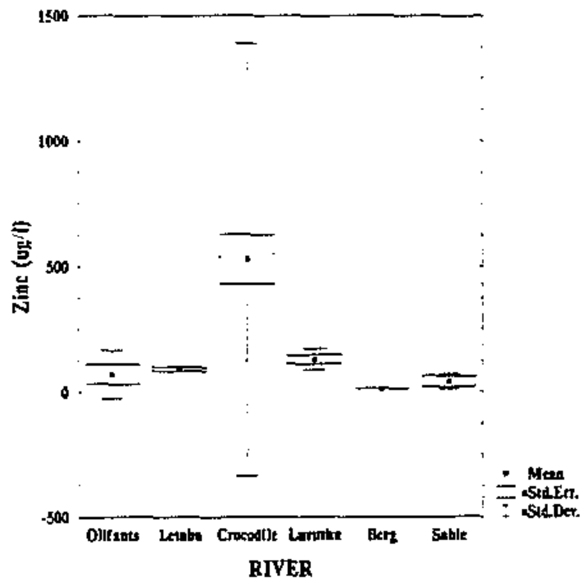


Figure 11b: Ortho-phosphate, nitrite and nitrate for all rivers sampled.





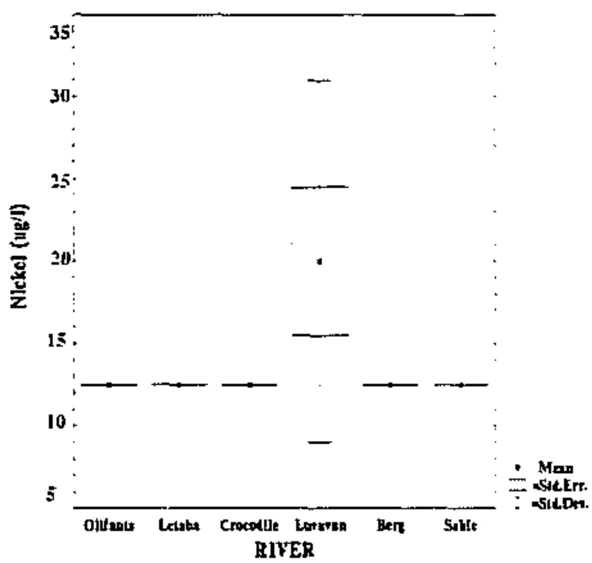


Figure 12: Iron, nickel and zinc in water for all rivers sampled.

4.3 Fish Biology (Length, Weight, Age, Gonadotrophic Index and Bioconcentration Factor)

The mean standard lengths and weight of the fish caught in each river that were dissected and analyzed are presented in **Table 12** (full data set in Appendix B1). The mean standard length, weight, age and gonadotrophic indices per species of fish caught and analyzed for metals and pesticides respectively are indicated in **sections 4.6 and 4.7**.

4.3.1 Regression of standard length and weight

The regressions between standard length and weight was compared for *O. mossambicus* and *C. gariepinus* for the rivers that these species were collected (**Table 12**). Due to the bias as a result of the sampling methodology (large stretch mesh size used) selecting for larger specimens the regressions are not a true indication of the smaller size classes of the species selected for analysis. The best fit regression equation was:

$$\text{Mass} = a * \exp(b*SL), \text{ where } SL = \text{standard length}$$

The regression equations generated for the different rivers are indicated in **Table 13**.

Regression equations were used to compare the weight of the species of fish with the standard length and by so doing used to determine a "form of condition factor." Apart from *C. gariepinus* in the Olifants there was a strong closeness of fit between standard length and weight for the species and for the rivers. By comparing a set standard length for each species of fish the corresponding derived weight according to the regression equations will indicate a form of condition factor. For example if a standard length of 200 mm was compared for *O. mossambicus* and a standard length of 550 mm *C. gariepinus* and those regressed lengths against weight per river, the derived results are indicated in **Table 14**.

Table 12: Biological parameters measured (standard length, weight, age and gonadotrophic index) from the species of fish tissues were collected in the Berg (BER), Crocodile (CRO), Letaba (LET), Luvuvhu (LUV), Olifants (OLI) and Sabie (SAB) Rivers.

		Standard length (mm)					Mass (g)					Gonadotrophic index (GI)					Age (years)				
River/species		mean	N	min	max	Sd	mean	N	min	max	Sd	mean	N	min	max	Sd	mean	N	min	max	Sd
BER	Om	245	20	200	353	34.1	527	20	220	845	180.9	4.6	20	4	6	0.7	2.5	11	1.5	4	0.9
BER	Cc	419	10	290	510	67.2	2334	10	599	3750	1008.8	4.7	10	2	6	1.3	6.0	5	2	8	2.8
BER	Ms	330	2	330	330		1143	2	1143	1143	0.0	4.0	2	4	4		2.0	2	2	2	
BER	Md	348	2	348	348		923	2	923	523	0.0	5.0	2	5	5		3.0	2	3	3	
CRO	Om	293	19	246	327	23.2	1000	19	610	1440	228.3	4.4	19	3	5	0.7	4.1	8	2	5	1.0
CRO	C	529	72	308	841	115.1	1979	71	310	7250	1255.2	3.3	72	1	5	1.2	2.9	29	1	6	1.0
CRO	Si	253	3	252	254	1.2	224	3	215	242	15.9	2.2	3	2	2.5	0.3		0			0.0
CRO	Bm	322	41	210	465	63.2	964	41	200	2700	560.1	4.1	41	2	5	1.0	2.4	6	2	3	0.5
CRO	Lm	332	16	287	376	39.5	1099	16	635	1800	496.3	4.2	16	3.5	5	0.5		1			
CRO	Hv	315	3	286	329	24.8	460	3	300	450	138.6	1.0	3	1	1		1.0	1	1	1	
CRO	Tr	277	20	230	319	27.4	1003	20	619	1040	306.8	3.9	20	1	5	1.1	3.8	4	3	5	1.0
CRO	Lc	347	10	263	482	71.8	1183	10	460	2500	670.3	3.5	10	2	5	1.4	3.5	4	3	5	1.0
CRO	Lr	224	1				570	1			0.0	2.7	1								
LET	Om	247	30	161	615	77.7	635	30	89	3250	565.7	3.2	30	1	5	1.2	2.5	17	1	4	1.1
LET	C	511	21	343	764	110.6	2067	21	545	6250	1658.2	3.2	21	1	5	1.3	2.9	7	1	4	1.5
LET	Si	266	6	234	278	17.0	290	6	182	345.6	59.2	2.8	6	1.8	3.8	0.7	2.3	3	1.5	3	0.8
LET	Bm	251	4	214.3	275	26.0	377	4	246.7	520	114.5	4.2	4	3.3	6	1.2	2.0	1	2	2	
LET	Lm	239	3	234.3	248	7.5	336	3	146.67	484	172.3	3.8	3	1.5	5	2.0					
LET	Lr	258	5	225	300	34.0	491	5	320	827	214.2	1.3	5	1	2	0.5	3.4	5	2	5	1.3
LET	Lrd	171	1				104	1			0.0	1.0	1				1.5	1			
LUV	Om	198	6	175	240	24.6	327	6	242	548	118.6	2.3	6	2	3	0.4	4.0	1	4	4	
LUV	C	448	16	370	550	52.7	1063	16	590	1870	368.4	2.2	16	1	6	1.6	3.1	14	2	5	1.0
LUV	Bm	344	5	320	360	21.9	891	5	727	1000	149.5	2.6	5	2	3	0.6	2.4	5	2	3	0.6
LUV	Hv	440	2	440	440		1720	2	1720	1720	0.0	4.0	2	4	4						
LUV	Lc	319	5	295	350	20.0	985	5	766	1348	216.1	1.2	5	1	2	0.5	2.0	2	2	2	
LUV	Lr	313	2	305	320	10.6	1026	2	855	1196	241.1	1.0	2	1	1		2.0	2	2	2	
OLI	Om	225	10	173	280	42.6	527	10	223.5	933	304.5	3.7	10	1	6	1.9	2.4	7	1	4	1.3
OLI	Cc	640	1				6000	1				5.0	1								
OLI	C	570	37	205	980	169.9	2576	37	83	13000	2755.8	2.5	31	1	6	1.3	3.5	22	2	6	1.2
OLI	Bm	312	2	272.5	352	56.2	788	2	500	1075	406.6	3.5	2	2	5	2.1	2.5	2	1	4	2.1
OLI	Lc	319	9	305	335	11.0	845	9	762	975	84.0	1.9	9	1	2	0.3	2.4	7	2	3	0.5
OLI	Lr	283	2	270	295	17.7	560	2	446	674	161.2	4.5	2	4	5	0.7					
OLI	Lrd	235	6	215	260	20.5	350	6	270	452	83.2	2.7	6	1	6	2.6	3.0	4	3	3	
SAB	Om	258	2	240	275	24.8	702	2	581	822	170.4	2.5	2	2	3	0.7					
SAB	C	591	4	435	690	123.3	2620	4	1078	3750	1347.8	2.5	4	2	4	1.0					
SAB	Si	292	3	282	310	15.4	413	3	357	502	77.9	2.8	3	2.5	3	0.3	2.5	2	1	4	2.1
SAB	Bm	337	7	287	392	45.0	1100	7	550	1700	465.1	1.7	7	1	2	0.5	3.0	1	3	3	
SAB	Hv	331	2	312	350	26.9	733	2	605	860	180.3	2.0	2	2	2						
SAB	Lc	311	8	290	333	16.0	933	8	809	1282	164.8	1.8	8	1	2	0.5	3.0	2	2	4	1.4
SAB	Lr	313	7	289	342	17.8	966	7	699	1211	180.8	2.1	7	1	4	0.9	4.0	1	4	4	

Table 13: **Regression values of mass and standard length for *O.mossambicus* and *C. gariepinus* for the rivers studied.**

Formula	a	b	R^2	a	b	R^2
	O. mossambicus			*C. gariepinus*		
Berg	186.4	0.0038	0.26			
Crocodile	72.6	0.0088	0.86	147.9	0.0045	0.91
Letaba	20.68	0.0135	0.87	120.0	0.0052	0.86
Luvuvhu	18.61	0.0141	0.98	71.8	0.0059	0.96
Olifants	20.09	0.0132	0.95	200.6	0.0039	0.83
Sabie	32.67	0.0118	0.99	129.8	0.0049	1.0

Table 14: **Comparison of regressed weight for *O.mossambicus* and *C. gariepinus* per river.**

River	Regressed weight (g)	
	O. mossambicus (200mm)	*C. gariepinus* (550 mm)
Berg	399	
Crocodile	422	1757
Letaba	308	2095
Luvuvhu	312	1843
Olifants	282	1714
Sabie	346	1922

4.3.2 Bioconcentration factors (BCF)

Bioconcentration factors (BCF) comparing the mean river water metal concentrations with the mean metal loads in the fish tissues per river are indicated in **Table 15**. The BCF's indicated a large variation between rivers and tissues. For the metals analyzed the following tissues and rivers indicated the highest BCF values:-

- manganese and aluminium in the gut of fish in Letaba River
- iron in the liver of fish in the Sabie River
- zinc and nickel in the liver of fish in the Berg River
- copper in the liver of fish in the Olifants River

Table 15: Bioconcentration factors (BCF) for metals in various fish tissues for different rivers.

		Al	Co	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
Berg	Liver	113				2724		7	94		3622
	Gills	124				112		7	616		3682
	Ovaries	69				122		5	216		2346
Crocodile	Liver		6	108	79	3574	322	6	26	46	50
	Gills			231	37	182	89		157	167	106
	Ovaries		10	5	20	167	72	9	13	29	101
	Fat		25	18	184	54	62	24	15	169	7
	Flesh		5	11	19	33	12	5	4	13	8
	Testes			8	33	142	38	7	26	45	44
	Gut			324	969	436	2		790	600	40
Letaba	Liver	109		88		2452	1103		42	34	309
	Gills	82		13		78	92		376		344
	Ovaries			9		114	35			118	740
	Fat			124		12	45		16	43	15
	Flesh	86		144		137	248		33		68
	Testes			11		43	184		68	73	166
	Gut	8249		80		308	1415	56	2146		245
Luvuvhu	Liver					1725	727		15		501
	Gills					32	285		79		430
	Ovaries					31	73		5		299
Olifants	Liver	41	104	195	31	6117	1347	300	12		626
	Gills	68	26	13	46	111	336	23	71		9
	Ovaries	17	58	80	15	25	446	6	2		682
	Fat	23	83	272	334		373				111
	Testes	84	48	68	38	33	339	139	45		566
Sabie	Liver	84		65			1606		79		708
	Gills	223		21			670		477		1265

4.4 Stomach Content Analysis

The stomach contents of the species of fish with distinct stomachs were combined for all the rivers (**Figure 13, Appendix B2**). The combined contents of the foregut of the species of fish with no distinct stomachs (*B. marequensis, H. molitrix, L.congoro, L. rosae, L. ruddi and L. molybdinus*) are indicated in **Table 16**.

The stomachs of the largemouth bass (*M. salmoides*) and smallmouth bass (*M. dolomieu*) were empty. These bass eat fish, crabs, snails, etc. (Skelton 1993). The carp eat a wide range of plant and animal material by grubbing in the sediments (Skelton 1993).

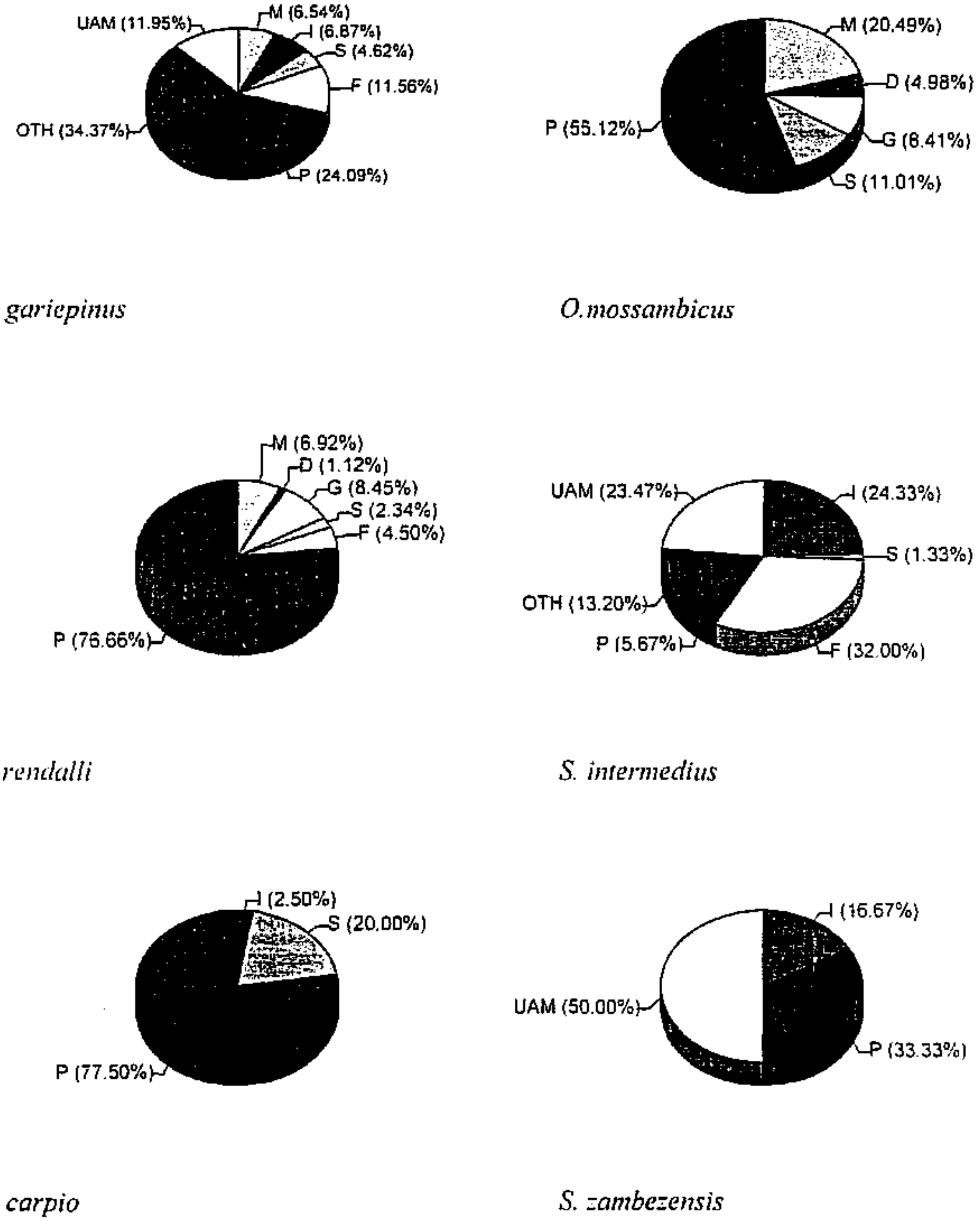


Figure 13 : Stomach content analysis for species of fish with distinct stomachs - all rivers combined.

The results of the stomach content analysis of the fish for the Crocodile and Letaba Rivers are indicated in **Figure 14**. There were dietary difference between the rivers for some of the fish species especially for *C. gariepinus*, *O. mossambicus* and *S. intermedius*. The *C. gariepinus* in the Crocodile River were mainly eating plant and detritus whilst the same species in the Letaba River were more omnivorous (**Figure 14**). The *O. mossambicus* in the Letaba River were eating a wider variety of algal material when compared to the same species in the Crocodile River. The *S. intermedius* in the Letaba River were eating a large percentage of fish which made up less than a percent in the diets of the same species in the Crocodile River.

Table 16: Predominant fore-gut contents for species analyzed.

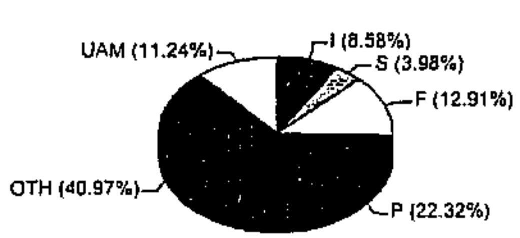
Species	Predominant fore-gut contents
B. marequensis	Aquatic insects, algae, snails
H. molitrix	Phytoplankton
L. congoro	Algae
L. rosae	Detritus, invertebrates
L. ruddi	Detritus (organic sediment)
L. molybdinus	Algae
C. carpio	Omnivorous (grubs in sediment)

4.5 Species and Tissue Selection for Metal and Pesticide Determination

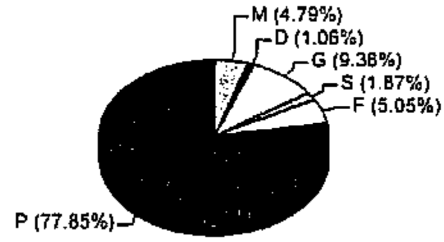
Species and tissue selection in the rivers studied was determined by the following factors:-

- natural distribution
- catchability of fish (abundance and habitat preference),
- seasonal availability (fish migration and river flows according to rainfall),
- size of fish caught,
- the large weight of tissues that were required for pesticide (15 g) and metal (10 g) analysis.

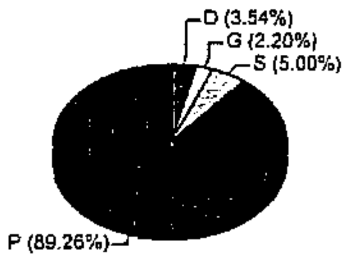
The tissues that were sampled for pesticide and metal analysis per species and river are indicated in **Table 17**. The tissue weight requirements for metal and pesticide determination meant that the number of fish, size, weight etc. varied between metals and pesticides. The mean standard lengths (SL), weight, gonadotrophic index (GI) and the number of tissues analyzed of fish sampled for metal and pesticide analysis are indicated in **Table 18a** and **Table 18b** respectively.



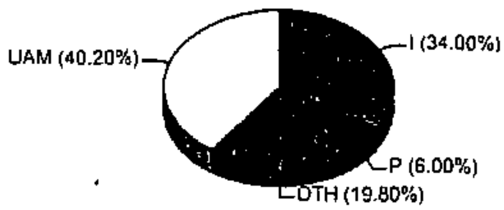
Crocodile River: *C. gariepinus*



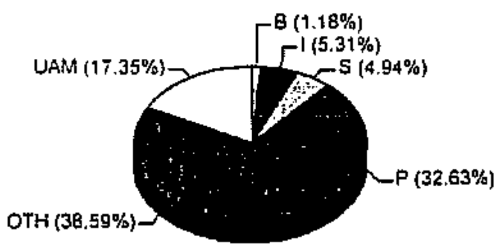
Crocodile River: *T. rendalli*



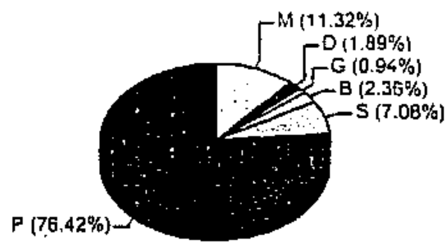
Crocodile River: *O. mossambicus*



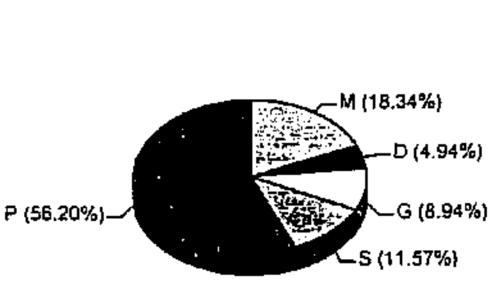
Crocodile River: *S. intermedius*



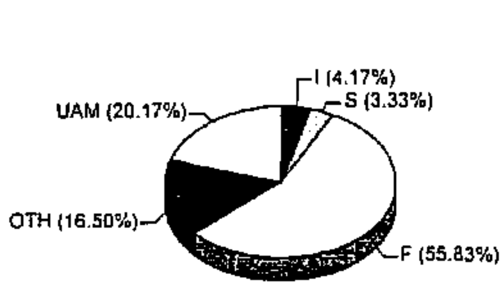
Letaba River: *C. gariepinus*



Letaba River: *T. rendalli*



Letaba River: *O. mossambicus*



Letaba River: *S. intermedius*

Figure 14: Stomach content analysis for species of fish with distinct stomachs in the Crocodile and Letaba Rivers.

Table 17: **Tissues sampled from specific species of fish for pesticide and metal analysis in the Letaba, Olifants, Sabie, Luvuvhu, Crocodile and Berg Rivers.** (Blank spaces indicate no tissues collected for a specific species)

River and species	Liver	Testes	Ovaries	Fat	Gills	Gut	Flesh
Berg River							
C. carpio	✓	✓	✓	✓	✓		
O. mossambicus	✓		✓	✓	✓		
M. dolomieu	✓		✓		✓		
M. salmoides	✓				✓		
Crocodile River							
B. imberi			✓				
B. marequensis	✓	✓	✓	✓	✓	✓	✓
C. gariepinus	✓	✓	✓	✓	✓		✓
H. vittatus	✓		✓	✓		✓	✓
L. congoro	✓	✓	✓				✓
L. molybdinus	✓	✓	✓			✓	✓
L. rosae	✓		✓			✓	✓
O. mossambicus	✓	✓	✓	✓			✓
S. intermedius	✓		✓				✓
S. zambezensis			✓				
T. rendalli	✓	✓	✓	✓	✓		✓
Letaba							
B. marequensis	✓	✓	✓	✓			
C. gariepinus	✓	✓	✓	✓			
L. molybdinus	✓	✓	✓				✓
L. rosae	✓	✓		✓		✓	
O. mossambicus	✓		✓	✓		✓	✓
S. intermedius	✓		✓				
Luvuvhu							
C. gariepinus	✓			✓	✓		
L. congoro	✓			✓	✓	✓	
L. rosae	✓			✓	✓		
O. mossambicus	✓			✓	✓		
H. vittatus	✓		✓		✓		
B. marequensis	✓			✓	✓		
Olifants							
C. gariepinus	✓	✓	✓	✓	✓		✓
L. rosae	✓	✓	✓	✓	✓		✓
O. mossambicus	✓		✓	✓	✓		
S. intermedius			✓				
B. marequensis	✓		✓		✓	✓	
L. congoro	✓		✓		✓		✓
L. ruddi	✓						✓
H. molitrix	✓		✓				
Sabie							
B. marequensis	✓		✓	✓			
C. gariepinus	✓		✓				
H. vittatus				✓			
L. congoro	✓		✓	✓		✓	
L. rosae	✓		✓	✓		✓	
L. ruddi				✓			
O. mossambicus				✓			
S. intermedius	✓		✓				

Table 18a: **Number, mean (± standard deviation), standard length (SL), weight, gonadotrophic index (GI) of the fish sampled for metal analysis.**

Species	n	Standard length (mm)	Mass (g)	GI	Age (years)
O. mossambicus	87	251.00 ± 57.62	657.76 ± 420.34	3.77 ± 1.27	2.81 ± 1.19
C. carpio	10	419.40 ± 67.24	2334.10 ± 1008.78	4.70 ± 1.32	6.00 ± 2.83
M. salmoides	2	330.00 ± 0.00	1143.00 ± 0.00	4.00 ± 0.00	2.00 ± 0.00
M. dolomieu	2	348.00 ± 0.00	923.00 ± 0.00	5.00 ± 0.00	3.00 ± 0.00
C. gariepinus	150	529.39 ± 129.52	2058.62 ± 1788.92	2.98 ± 1.35	3.13 ± 1.11
S. intermedius	12	269.29 ± 20.01	304.15 ± 88.51	2.64 ± 0.56	2.40 ± 1.19
B. marequensis	59	320.20 ± 59.15	928.28 ± 519.71	3.67 ± 1.25	2.44 ± 0.72
L. molybdinus	19	316.96 ± 49.96	978.10 ± 538.70	4.12 ± 0.81	
H. vittatus	7	355.14 ± 61.15	897.86 ± 584.89	2.14 ± 1.35	1.00 ± 0.00
T. rendalli	20	277.01 ± 27.42	1002.73 ± 306.83	3.88 ± 1.06	3.75 ± 0.96
L. congoro	32	325.80 ± 43.06	994.60 ± 404.13	2.23 ± 1.18	2.73 ± 0.88
L. rosae	17	288.11 ± 36.44	762.53 ± 293.67	2.07 ± 1.22	3.12 ± 1.19
L. ruddi	7	225.89 ± 30.52	314.80 ± 120.15	2.43 ± 2.44	2.70 ± 0.67
H. molitrix	1	640.00 ± 0.00	6000.00 ± 0.00	5.00 ± 0.00	

Table 18b: **The mean (± standard deviation) for fish standard length (SL), weight, gonadotrophic index(GI) and the number of fish tissues sampled for pesticide analysis.**

Species of fish	n	SL (mm)	Mass (g)	GI	Age (years)
O. mossambicus	67	258.32 ± 36.71	699.47 ± 273.70	3.83 ± 1.04	3.46 ± 1.33
C. carpio	10	448.40 ± 83.39	2819.20 ± 1367.23	4.95 ± 0.83	5.40 ± 2.41
M. dolomieu	1	348.00 ± 0.00	923.00 ± 0.00	5.00 ± 0.00	3.00 ± 0.00
L. molybdinus	24	292.24 ± 54.39	789.00 ± 491.41	4.33 ± 0.80	2.14 ± 0.90
B. marequensis	51	310.10 ± 59.84	898.83 ± 580.73	3.86 ± 1.38	3.00 ± 1.03
H. vittatus	4	348.25 ± 67.83	991.25 ± 541.33	3.25 ± 1.50	2.50 ± 0.71
C. gariepinus	109	571.53 ± 167.56	2880.73 ± 2811.80	3.37 ± 1.35	3.28 ± 1.39
L. rosae	17	291.71 ± 40.57	699.40 ± 294.21	3.02 ± 1.43	2.54 ± 0.50
T. rendalli	19	270.21 ± 25.61	974.37 ± 256.70	3.76 ± 0.66	3.00 ± 0.00
S. zambezensis	1	295.00 ± 0.00	200.00 ± 0.00	5.00 ± 0.00	
L. congoro	17	345.85 ± 52.47	1125.07 ± 420.23	2.61 ± 1.71	2.65 ± 1.42
B. imberi	1	185.00 ± 0.00	185.00 ± 0.00		
S. intermedius	7	254.26 ± 23.75	257.99 ± 76.24	2.91 ± 0.55	3.00 ± 1.00
L. ruddi	1	289.00 ± 0.00	699.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00

4.6 Bioaccumulation of Metals

The results of the metal bioaccumulation studies in fish determined for per river, site, species and tissue, are indicated in **Appendix C**. The maximum values of the metals (in tissues, species and rivers) indicate that there are several outliers in each catchment and there is a large range of metal values. These high values can be related to species, sites and tissues (Section 4.6.1 - 4.6.6). The results are expressed as µg/g on a dry weight basis in fish tissues.

The biological parameters for all the species sampled as presented in **Table 18a** illustrate the values and ranges for all these parameters. It is evident that the size parameters are limited due to the selective sampling methods.

4.6.1 Metals concentrations in fish tissues

Appendix C1 indicates the mean metal loads per tissue by combining all the species of fish in the rivers sampled.

The following null hypothesis is tested:
The levels of the specified metals in different tissues do not represent populations with the same medians.

The null hypothesis is rejected for As and Mg on the 95% confidence limit. The null hypothesis is accepted for Al, Cd, Cr, Co, Cu and Fe, indicating that the distribution of values for these metals have different medians for the tissues (**Table 19**).

The maximum values in the tissues (**Appendix C1**) indicate that there are several outliers in each catchment. A synthesis of the results, of the metal loads per tissue after combining all the species of fish analysed for metals indicating that the high mean values were usually found in the liver gills and to a lesser extent in the ovaries (**Table 20**).

Table 19: Summary of statistical analysis (Kruskall Wallis) showing analysis of variance between tissues for selected metals.

Tissues	Metal	Sample size	df	H	p
Liver, Gills, Ovaries, Flesh, Fat, Testes	Al	165	5	21.938	**0.001**
Liver, Gills, Ovaries	As	28	2	4.581	0.101
Liver, Gills, Ovaries, Flesh, Fat, Testes	Cd	358	5	110.165	**0.000**
Liver, Gills, Ovaries, Flesh, Fat, Testes	Cr	312	5	27.559	**0.000**
Liver, Gills, Ovaries, Flesh, Fat, Testes	Co	83	5	12.519	0.028
Liver, Gills, Ovaries, Flesh, Fat, Testes	Cu	375	5	258.855	**0.000**
Liver, Gills, Ovaries, Flesh, Fat, Testes	Fe	389	5	133.747	**0.000**
Liver, Ovaries, Testes	Mg	10	2	4.418	0.110
Liver, Gills, Ovaries, Flesh, Fat, Testes	Pb	120	5	21.444	**0.001**
Liver, Gills, Ovaries, Flesh, Fat, Testes	Mn	404	5	189.663	**0.000**
Liver, Gills, Ovaries, Flesh, Fat, Testes	Ni	225	5	24.214	**0.000**
Liver, Gills, Ovaries, Flesh, Fat, Testes	Zn	415	5	156.946	**0.000**
Liver, Gills, Ovaries	Hg	12	2	4.179	0.124

Table 20: The highest mean metal loads per tissue. (Tissues with less than three metal determinations were left not included).

Metal	Tissues			
	Liver	Gills	Ovaries	Testes
Al	x	xx		xxx
As	xxx	xx		
Cd	xxx	xx	x	
Cr	xx	x		xxx
Co	xxx		x	xx
Cu	xxx	xx		x
Fe	xxx	xx		x
Pb	xxx	xx		
Mg	xxx			
Mn	x	xxx		xx
Ni	x	xxx		xx
Zn	x	xxx	xx	

Where : xxx = highest means, xx = second highest means, x = third highest means.

The mean metal values in the fish tissues varied considerably from tissues to tissue. The maximum mean metal value in a tissue and the range of values per metal can be summarized below (**Table 20**):

Al = 1 080 μg/g in testes (range 5 to 9 782 μg/g),
As = 2.5 μg/g in liver (range 0.3 to 6.5 μg/g),
Cd = 1.02 μg/g in liver (range 0.02 to 10.9 μg/g),
Cr = 3.4 μg/g in testes (range 0.03 to 70.4 μg/g),
Co = 5.2 μg/g in liver (range 0.1 to 49.5 μg/g),
Cu = 336 μg/g in liver (range 0.3 to 6 802 μg/g),
Fe = 1 502 μg/g in liver (range 0.1 to 37 900 μg/g),
Hg = 0.07 μg/g in gills (0.7 to 0.003 μg/g),
Pb = 14.8 μg/g in liver (range 0.4 to 879 μg/g),
Mg = 5.0 μg/g in liver (0.7 to 8.5 μg/g),
Mn = 51.6 μg/g in gills (range 0.06 to 680 μg/g),
Ni = 6.1 μg/g in gills (range 0.03 to 42 μg/g),
Zn = 17.9 μg/g in gills (range 1.0 to 776 μg/g).

4.6.2 Metal loads between species of fish

Appendix C2 indicates the mean body loads of the metals analyzed per species of fish (rivers combined, N >3). There is a large variation in the mean metal concentrations between the species of fish. The following null hypothesis is tested:

The levels of the specified metals in different species do not represent populations with the same medians.

The null hypothesis is rejected for As, Cr, Co and Mg on the 95% confidence limit. The null hypothesis is accepted for Al, Cd, Cr, Cu, Fe, Pb, Mn, Ni and Zn, indicating that the distribution of values for these metals have different medians for the species (**Table 21**). The following is a synthesis of the species of fish studies with highest metal body loads and range (**Appendix C2**) : -

Table 21: Kruskall Wallis analysis of variance between tissues for selected metals (significant numbers are bold).

Species	Metal	Sample size	df	H	p
Om, Cc, Ms, Md, Bm, C, Si, Lc, Lr, Lrd	Al	163	9	17.859	**0.037**
Om, Cc, Bm, Lm, C, Tr, Lc	As	28	6	5.213	0.517
Om, Cc, Bm, Lm, C, Tr, Si, Lc, Lr, Lrd	Cd	351	9	53.119	**0.000**
Om, Bm, Lm, C, Tr, Si, Hv, Lc, Lr, Lrd	Cr	315	9	10.977	0.277
Om, Cc, Bm, Lm, C, Si, Hv, Lc, Lr, Lrd	Co	86	9	16.653	0.055
Om, Cc, Bm, Lm, C, Tr, Si, Lc, Lr, Lrd	Cu	370	9	53.806	**0.000**
Om, Bm, Lm, C, Tr, Si, Hv, Lc, Lr, Lrd	Fe	392	9	50.597	**0.000**
Om, Bm, C, Si	Mg	10	3	2.040	0.564
Om, Cc, Bm, Lm, C, Si, Hv, Lc, Lr, Lrd	Pb	119	9	36.463	**0.000**
Om, Cc, Bm, Lm, C, Tr, Si, Lc, Lr, Lrd	Mn	397	9	23.922	**0.004**
Om, Bm, Lm, C, Tr, Si, Hv, Lc, Lr	Ni	226	8	20.243	**0.010**
Om, Cc, Bm, Lm, C, Tr, Si, Lc, Lr, Lrd	Zn	408	9	63.401	**0.000**

The following is a synthesis of the species of fish studied with highest mean metal body loads and range (Appendix C2):-

Al : *L. rosae* (920 μg/g) > *L. congoro* (192 μg/g) > *C. gariepinus* (173 μg/g), range 5 to 69782 μg/g,

As : *O. mossambicus* (3.0 μg/g) > *B. marequensis* (2.2 μg/g) > *C. gariepinus* (2.0 μg/g) range 0.3 to 6.5 μg/g,

Cd : *L. congoro* (2.2 μg/g) > *L. rosae* (2.1 μg/g) > *C. carpio* (0.8 μg/g) range (0.02 to 10.9,

Co : *L. rosae* (5.2 μg/g) > *C. gariepinus* (5.0 μg/g) > *O. mossambicus* (3.5 μg/g) range 0.1 to 49.5 μg/g,

Cr : *L. rosae* (12.7 μg/g) > *O. mossambicus* (3.6 μg/g) > *L. congoro* (3.1 μg/g) range 0.03 to 70.4,

Cu : *L. ruddi* (1 078 μg/g) > *L. rosae* (689 μg/g) > *L. congoro* (493 μg/g) range 0.3 to 6 802 μg/g,

Fe : *H. vittatus* (1 772 μg/g) > *C. gariepinus* (1 558 μg/g) > *O. mossambicus* (1 080 μg/g) range 0.03 to 37 900 μg/g, Mn : *C. carpio* (48.8 μg/g) > *L. rosae* (47.7 μg/g) > *L. ruddi* (47.3 μg/g) range 0.4 to 680 μg/g,

Pb : *L. rosae* (304 μg/g) > *O. mossambicus* (2.7 μg/g) > *C. gariepinus* (1.6 μg/g) range 0.4 to 879 μg/g,

Ni : *O. mossambicus* (3.4 μg/g) > *T. rendalli* (3.2 μg/g) > *B. marequensis* (1.8 μg/g) range 0.09 to 41.7 μg/g,

Zn : *C. carpio* (269 μg/g) > *L. rosae* (176 μg/g) > *L. congoro* (153 μg/g) range 1 to 776 μg/g.

4.6.3 Metal loads between tissues per species

Figure 15a and **Figure 15b** indicates the combined metal loads per species of fish and per tissue. It indicates the tissues responsible for the high metal loads in the specific species of fish. In order of priority, from highest to lowest, the species with highest body metal loads (**Appendix C3**) are: *L. rosae, O. mossambicus, C. carpio* and *C. gariepinus, L. ruddi* and *L. congoro*. Only these six species of fish will be commented on below.

L. rosae

The liver was responsible for the high mean metal loads of Fe (1 021 μg/g) and Cu (856 μg/g); gills for high Zn values (368 μg/g) and the gut responsible for the rest of the high metal values (**Figure 15a**). The sample size for the gut is only one and the high analysis is probably due to the detritus (sand) in the gut. No conclusions can be determined by this single gut sample.

O. mossambicus

The high body loads in this species are due to the liver (As, Cd, Cr, Co, Cu, Fe, Mg, Pb, Ni); gills (Al, Mn) and ovaries (Zn) (**Figure 15a** and **Figure 15b**).

C. gariepinus

The high body loads in this species are due to the liver (Cd, Cr, Co, Cu, Fe); gills (Al, Pb, Mn, Zn) and fat (Cr, Ni) (**Figure 15a** and **Figure 15b**).

C. carpio

The body high loads of this species are due to the liver (Al, As, Cd, Cu, Hg) and gills (Pb, Mn, Zn) (**Figure 15a** and **Figure 15b**).

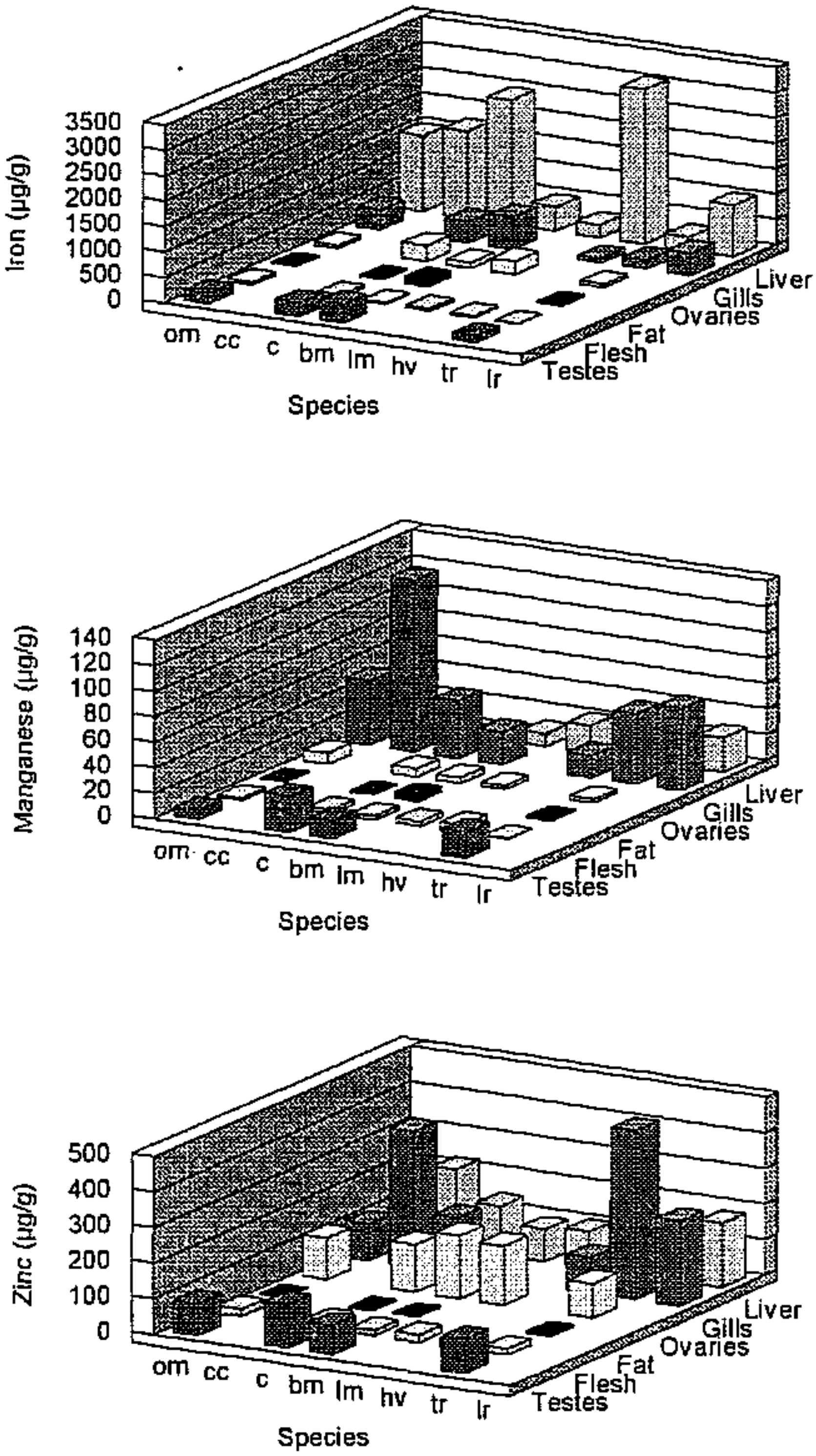
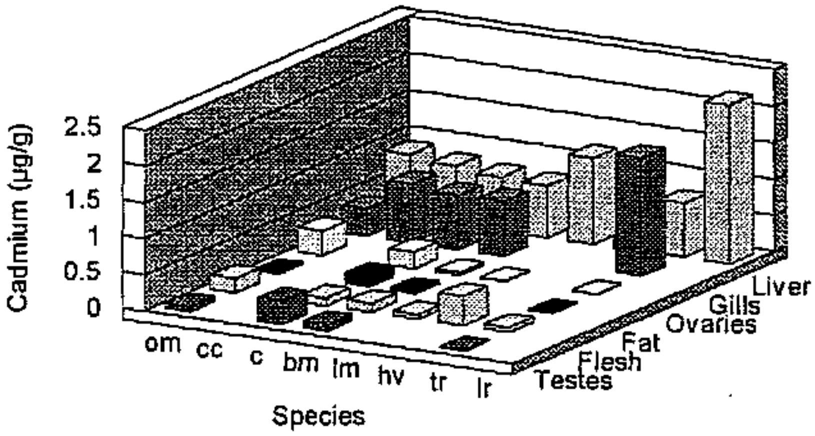
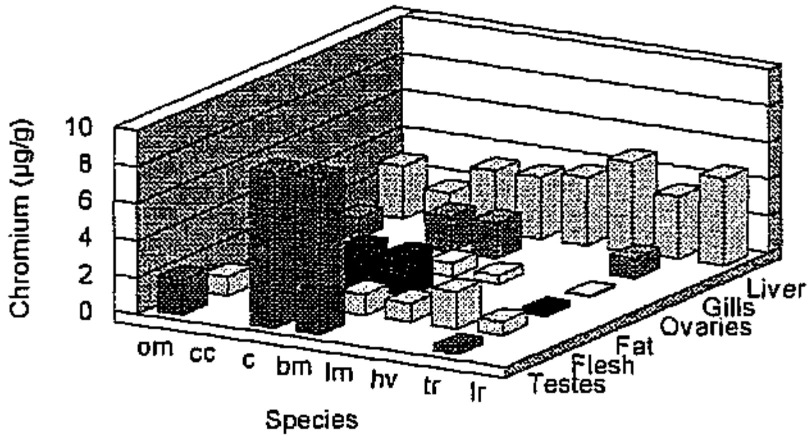


Figure 15a: **The mean of the body loads for iron, manganese and zinc in all the fish tissues analyzed per species.**





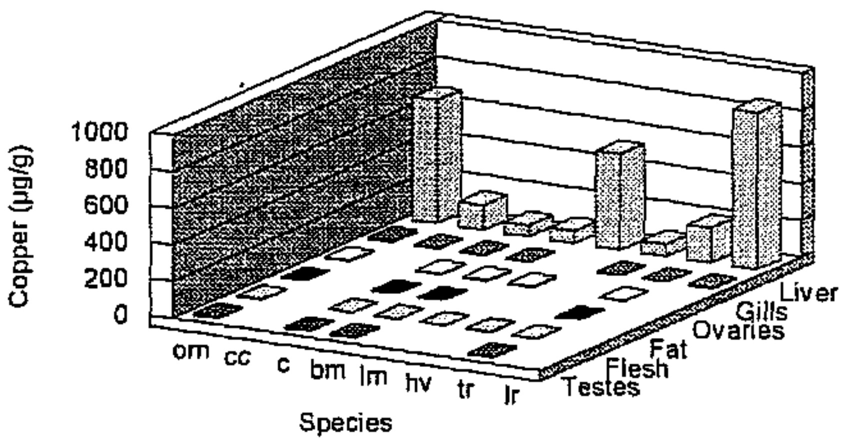


Figure 15b: The mean of the body loads for cadmium, chrome and copper in all the fish tissues analyzed per species.

L. congoro

With the exception of Al, Mn and Zn (gills), the liver had the highest metal load in this species (**Figure 15a** and **Figure 15b**).

L. ruddi

The gills had the highest loads for Al, Co, Mn and Zn, the liver had the highest loads for Cd, Cr, Cu and Fe (**Figure 15a** and **Figure 15b**).

From the analysis above it indicates that the following tissues have consistently higher metals in the species of fish analyses irrespective of river:

Liver :- Fe, Cu, As, Cd, Co, Mg, Ni, Cd, Hg
Gills :- Zn, Al, Mn
Testes :- Al, Cr (see section 4.6.1)

4.6.4 Fish metals loads in each river

The mean (standard deviation and range) of the combined fish tissues per river are indicated in **Appendix C4**. The following null hypothesis is tested:

The levels of the specified metals in different rivers do not represent populations with the same medians.

The null hypothesis is rejected for As, Cr and Ni on the 95% confidence limit. The null hypothesis is accepted for Al, Cd, Co, Cu, Fe, Pb, Mn and Zn, indicating that the distribution of values for these metals have significantly different medians for the different rivers (**Table 22**).

Table 22: Kruskall Wallis analysis of variance between rivers for selected metals.

Rivers	Metal	Sample size	df	H	p
Ber, Cro, Let, Oli, Sab	Al	168	4	17.076	**0.002**
Ber, Cro	As	28	1	0.001	0.981
Ber, Cro, Let, Oli, Sab	Cd	360	4	18.453	**0.001**
Cro, Let, Oli	Cr	316	2	0.295	0.863
Cro, Let, Oli	Co	86	2	26.184	**0.000**
Ber, Cro, Let, Luv, Oli	Cu	379	4	46.980	**0.000**
Cro, Let, luv, Oli, Sab	Fe	393	4	86.041	**0.000**
Ber, Cro, Let, Oli	Pb	123	3	36.105	**0.000**
Ber, Cro, Let.,Luv, Oli, Sab	Mn	408	5	23.356	**0.000**
Cro, Let	Ni	226	1	0.506	0.477
Ber, Cro, Let, Luv, Oli, Sab	Zn	419	5	69.003	**0.000**

The mean metal values detected in the lumped fish tissues per river indicate the following order of metal loads per river sampled (**Figure 15a** to **Figure 15b**):

- Al : Letaba (612 $\mu g/g$) > Olifants (214 $\mu g/g$) > Crocodile (92 $\mu g/g$) > Berg (88 $\mu g/g$) > Sabie (87 $\mu g/g$),
- As : Berg (2.7 $\mu g/g$) > Crocodile (2.3 $\mu g/g$)
- Cd : Olifants (1.2 $\mu g/g$) > Sabie (0.9 $\mu g/g$) > Crocodile (0.7 $\mu g/g$) > Letaba (0.7 $\mu g/g$) > Berg (0.7 $\mu g/g$),
- Cr : Letaba (3.6 $\mu g/g$) > Crocodile (3.2 $\mu g/g$) > Olifants (2.0 $\mu g/g$)
- Co : Letaba (9.6 $\mu g/g$) > Olifants (4.9 $\mu g/g$) > Crocodile (0.3 $\mu g/g$)
- Cu : Olifants (520 $\mu g/g$) > Letaba (301 $\mu g/g$) > Luvuvhu (194 $\mu g/g$) > Crocodile (98 $\mu g/g$) > Berg (62 $\mu g/g$),
- Fe : Letaba (2 134 $\mu g/g$)> Luvuvhu (975 $\mu g/g$) > Olifants (941 $\mu g/g$) > Sabie (922 $\mu g/g$) > Crocodile (653 $\mu g/g$),
- Pb : Olifants (17.6 $\mu g/g$) > Letaba (3.4 $\mu g/g$) > Crocodile (0.6 $\mu g/g$) > Berg (0.5 $\mu g/g$),
- Mn : Luvuvhu (75.5 $\mu g/g$) > Berg (23.1 $\mu g/g$) > Olifants (20.1 $\mu g/g$) > Letaba (17.7 $\mu g/g$) > Crocodile (16.5 $\mu g/g$) > Sabie (11.7 $\mu g/g$),
- Ni : Crocodile (2.1 $\mu g/g$) > Letaba (1.7 $\mu g/g$)
- Zn : Luvuvhu (200 $\mu g/g$) > Olifants (170 $\mu g/g$) > Berg (135 $\mu g/g$) > Sabie (114 $\mu g/g$) > Letaba (95 $\mu g/g$) > Crocodile (84 $\mu g/g$).

4.6.5 Comparison of the fish metal loads between sites in each river

Appendix C5 indicates the metal body loads per site in each river for the fish analyzed and the statistics between sites per river. Trends per river for the metal values were compared between sites from the highest upstream site to the lowest downstream site. High metal values per site could indicate point or diffuse sources of metal pollution.

4.6.5.1 Berg River

The following null hypothesis is tested for the sites in the Berg River: *The levels of the specified metals at different sites do not represent populations with the same medians.*

The null hypothesis is rejected for the Berg river sites for As, Cd, Cr, Co, Cu, Pb, Mn and Hg on the 95% confidence limit. The null hypothesis is accepted for Al and Zn, indicating that the distribution of values for these metals have different medians for the two sites (**Table 23**). With the exception of aluminium and zinc the values of metals in the fish tissues are similar in then Voëlvlei Dam and at Misverstand Weir. Aluminium (mean 11.1 µg/ℓ) is markedly higher at Misverstand weir with manganese and zinc higher at Voëlvlei Dam.

Table 23: Kruskall Wallis analysis of variance between sites for selected metals in the Berg River.

Sites	Metal	Sample size	df	H	p
Misverst, Voelvlei	Al	34	1	10.080	**0.002**
Misverst, Voelvlei	As	13	1	0.327	0.567
Misverst, Voelvlei	Cd	34	1	0.843	0.359
Misverst, Voelvlei	Cu	34	1	0.241	0.623
Misverst, Voelvlei	Pb	34	1	2.758	0.097
Misverst, Voelvlei	Mn	34	1	0.051	0.821
Misverst, Voelvlei	Zn	34	1	4.480	**0.034**
Misverst, Voelvlei	Hg	12	1	3.103	0.078

4.6.5.2 Crocodile River

The following null hypothesis is tested for the sites in the Crocodile River: *The levels of the specified metals at different sites do not represent populations with the same medians.*

The null hypothesis is rejected for the Crocodile River sites for Al, As, Cd, Cr, Co, Cu, Fe, Mg, Ni, Zn and Hg on the 95% confidence limit. The null hypothesis is accepted for Mn indicating that the distribution of values for Mn have different medians for the sites (**Table 24**).

The metal results of the fish at each of the Crocodile River sites (**Appendix C5**) indicate the following:

- There is no clear trend for aluminium down the length of the river with Lions Club indicating the highest values.

- Arsenic indicates similar means and ranges for all sites.

- Cadmium indicates no trend with recorded values similar for all sites.

- Chromium values indicate no trend with the highest values at Tenbosch.

- Copper indicate no trend upstream of the Kaap River confluence but the lowest two sites (Riverside and Tenbosch) have the highest values indicating a possible copper source.

- There is no iron trend with Riverside, Angling Club and Lions Club having the highest values. This could indicate a sources of iron near Nelspruit and Malelane.

- Manganese results indicate that there is a source around Nelspruit as the values increase below the town down to Tenbosch.

- Nickel values indicate no clear trend with Tenbosch having the highest values.

- Zinc values, although similar, indicate a possible increase down the length of the river.

Table 24: Kruskall Wallis analysis of variance between sites for selected metals in the Crocodile River.

Sites	Metal	Sample size	df	H	p
Lions_cl, Tenbosch, Mataffin, Rvuletts	Al	11	3	2.379	0.498
Lions_cl, Rverside, Tenbosch, Mataffin, Rvuletts	As	15	4	5.806	0.214
Croc_hot, Hngel_cl, Lions_cl, Rverside, Tenbosch, Mataffin, Rvuletts	Cd	178	6	8.348	0.214
Croc_hot, Hngel_cl, Lions_cl, Rverside, Tenbosch, Mataffin, Rvuletts	Cr	178	6	10.726	0.097
Lions_cl, Rverside, Tenbosch, Mataffin	Co	27	4	0.000	1
Lions_cl, Rverside, Tenbosch	Cu	178	6	7.092	0.313
Croc_hot, Hngel_cl, Lions_cl, Rverside, Tenbosch, Mataffin, Rvuletts	Fe	186	6	5.634	0.465
Croc_hot, Hngel_cl, Lions_cl, Rverside, Tenbosch, Mataffin, Rvuletts	Mn	178	6	13.937	**0.030**
Croc_hot, Hngel_cl, Lions_cl, Rverside, Tenbosch, Mataffin, Rvuletts	Ni	178	6	8.774	0.187
Croc_hot, Hngel_cl, Lions_cl, Rverside, Tenbosch, Mataffin, Rvuletts	Zn	186	6	6.929	0.328

4.6.5.3 Letaba River

The metal results of the fish at the sites sample in the Letaba River indicate the following (**Appendix C5**). The null hypothesis is rejected for the Letaba River sites for Al, Cd, Cr, Cu, Mg, Mn, Ni and Zn on the 95% confidence limit. The null hypothesis is accepted for Fe indicating that the distribution of values for Fe have different medians for the sites (**Table 25**).

- The aluminium results indicate that the highest values recorded were in Hudson Ntsanwize Dam and in the Middle Letaba River. In the Groot Letaba River the highest mean annual aluminium levels were recorded in the fish at Prieska weir.

Table 25 : Kruskall Wallis analysis of variance between sites for selected metals in the Letaba River.

Sites	Metal	Sample size	df	H	p
Junction, Prieska, Slab, Pump_sta, Ranch16, Huson, Midlet	Al	22	6	4.243	0.643
Englhrdt, Junction, Prieska, Slab, Pump_sta, Drft_eng, Ranch16, Huson, Midlet	Cd	70	8	11.067	0.198
Englhrdt, Junction, Prieska, Slab, Pump_sta, Drft_eng, Ranch16, Huson, Midlet	Cr	70	8	10.382	0.239
Englhrdt, Junction, Prieska, Slab, Pump_sta, Drft_eng, Ranch16, Huson, Midlet	Cu	70	8	8.785	0.361
Englhrdt, Junction, Prieska, Slab, Pump_sta, Drft_eng, Ranch16, Huson, Midlet	Fe	70	8	15.715	**0.047**
Junction, Prieska, Slab, Pump_sta,	Mg	10	3	1.809	0.613
Englhrdt, Junction, Prieska, Slab, Pump_sta, Drft_eng, Ranch16, Huson, Midlet	Mn	59	8	9.299	0.318
Englhrdt, Junction, Prieska, Slab, Pump_sta, Drft_eng	Ni	48	5	6.355	0.273
Englhrdt, Junction, Prieska, Slab, Pump_sta, Drft_eng, Ranch16, Huson, Midlet	Zn	70	8	15.267	0.054

- The mean cadmium values were markedly higher at Camp 16 with no trend at the rest of the sites.

- Chromium values varied down the length of the Groot Letaba River, with the Pump Station having the highest mean value (5.2 ± 4.95 µg/g). In comparison the values in the Hudson Ntwanwisi Dam are markedly higher (mean 15.2 ± 29.44 µg/g).

- The copper values varied down the length of the study area.

- The iron values generally decreased down the length of the Letaba River with by far the highest values at the Junction Weir.

- The zinc values showed no trend throughout the Letaba catchment with the highest values in the Mid Letaba Dam.

4.6.5.4 Luvuvhu River

The null hypothesis is rejected for the Luvuvhu river sites for Cu, Fe and Mn on the 95% confidence limit. The null hypothesis is accepted for Zn indicating that the distribution of values for Zn have different medians for the sites (**Table 26**).

Table 26: Kruskall Wallis analysis of variance between sites for selected metals in the Luvuvhu River.

Sites	Metal	Sample size	df	H	p
Farm, Mkyaupst, Settlmnt, Mkyadnst	Cu	36	3	1.423	0.700
Farm, Mkyaupst, Settlmnt, Mkyadnst	Fe	36	3	3.740	0.291
Farm, Mkyaupst, Settlmnt, Mkyadnst	Mn	36	3	2.832	0.418
Farm, Mkyaupst, Settlmnt, Mkyadnst	Zn	36	3	9.841	**0.020**

4.6.5.5 Olifants River

The null hypothesis is rejected for the Olifants river sites for Cd, Cr, Mn and Zn on the 95% confidence limit. The null hypothesis is accepted for Al, Co, Cu, Fe and Pb indicating that the distribution of values for these metals have different medians for the sites (**Table 27**).

- The iron values indicated that the highest values were in the Arabie Dam and varied at the rest of the sites with no clear trend.
- The chromium values indicate no clear trends.
- The copper values were markedly higher in the Selati River due to mining activities, and declined further into the Kruger National Park.
- The aluminium values were highest at Arabie Dam and no trend was evident for the rest of the sites.
- The zinc values were similar throughout the Olifants River catchment.

Table 27: Kruskall Wallis analysis of variance between sites for selected metals in the Olifants River.

Sites	Metal	Sample size	df	H	p
Mamba_wr, Vyeboom, Baluli, Preselat, Pstselat, Selati, Arabie, Klipsprt	Al	68	7	15.559	**0.030**
Mamba_wr, Vyeboom, Baluli, Selati, Arabie	Cd	45	4	5.934	0.204
Mamba_wr, Vyeboom, Baluli, Preselat, Pstselat, Selati, Arabie, Klipsprt	Cr	68	7	4.277	0.747
Mamba_wr, Vyeboom, Baluli, Selati, Arabie, Klipsprt	Co	58	5	17.548	**0.004**
Mamba_wr, Baluli, Preselat, Pstselat,Selati, Arabie, Klipsprt	Cu	61	6	19.497	**0.003**
Mamba_wr, Vyeboom, Baluli, Preselat, Pstselat, Selati, Arabie, Klipsprt	Fe	68	7	16.628	**0.020**
Mamba_wr, Baluli, Preselat, Pstselat, Selati, Arabie, Klipsprt	Pb	61	6	30.535	**0.000**
Mamba_wr, Vyeboom, Baluli, Preselat, Pstselat, Selati, Arabie, Klipsprt	Mn	68	7	8.396	0.299
Mamba_wr, Vyeboom, Baluli, Preselat, Pstselat, Selati, Arabie, Klipsprt	Zn	68	7	9.503	0.219

4.6.5.6 Sabie River

As only one site was sampled in the Sabie River no statistical comparisons could be undertaken.

4.6.6 Metal loads of species of fish per river

Figure 16, **Figure 17** and **Figure 18 (Appendix C6)** indicates the metal loads per species of fish in each river. The following is a synthesis of this table.

Berg River:

C. carpio had the highest metal loads with the exception of arsenic (*O. mossambicus*) and there is no trend between species for lead.

Crocodile River:

The *Labeo* species had the highest metal loads in the Crocodile River with the exception of iron (*H. vittatus*), manganese (*O. mossambicus*) and zinc (*T. rendalli*).

Letaba River:

The *Labeo* species had the highest metal loads in the Letaba River with the exception of zinc (*S. intermedius*).

Luvuvhu River:

No trend with copper and zinc (*Labeo's*), iron (*C. gariepinus*), manganese (*O. mossambicus*).

Olifants River:

The *Labeo's* had the highest metal loads except for copper (*C. gariepinus*) and copper (*O. mossambicus*).

Sabie River:

No general trend with *H. vittatus* (iron), *L. rosae* (cadmium), *C. gariepinus* (manganese and zinc) and *O. mossambicus* (aluminium).

4.6.7 Gender metal differences between species

The following null hypothesis is tested: *The levels of the specified metals in males and females within species are not similar.*

The null hypothesis is accepted for *C. gariepinus* and *L. rosae* for Cd and *B. marequensis* for Cr indicating that there is significant differences between males and females for these samples. The null hypothesis is rejected for all other cases (**Table 28**).

Table 28: Mann Whitney U test (p) between males and females within species for all metals.

Metals	Species									
	All	Om	Cc	Bm	Lm	C	Tr	Hv	Lc	Lr
Al	0.741	0.152	0.855	0.221	1.000	0.077	1.000	1.000	0.382	1.000
As	0.770	0.909	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Cd	0.794	0.590	**0.045**	0.179	0.614	0.137	0.965	0.564	0.775	**0.028**
Cr	0.067	0.712	1.000	**0.039**	0.450	0.255	0.230	1.000	0.151	0.439
Co	0.407	0.497	1.000	1.000	1.000	0.531	1.000	1.000	1.000	1.000
Cu	0.428	0.632	0.201	0.222	0.900	0.303	0.424	0.564	0.903	0.558
Fe	0.950	0.554	1.000	0.650	0.314	0.236	0.744	0.699	0.663	0.874
Mg	0.086	0.121	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Pb	0.812	0.262	0.068	1.000	1.000	0.535	1.000	1.000	0.558	1.000
Mn	0.749	0.810	0.361	0.849	0.614	0.946	0.424	0.245	0.317	0.112
Ni	0.246	0.433	1.000	0.373	0.208	0.557	0.155	1.000	0.465	1.000
Zn	0.067	0.112	0.715	0.526	0.767	0.128	0.568	0.439	0.268	0.273
Hg	0.291	0.881	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

4.7 Bioaccumulation of Pesticides

The results of the pesticide bioaccumulation studies in fish determined per river, site, species and tissue, are indicated in **Appendix D**. The maximum values of the pesticides (in tissues, species and rivers) indicate that there are several outliers in each catchment and that there is a large range of pesticide values. The results are expressed as $\mu g/g$ (wet weight).

The species of fish (numbers and their biological characteristics) that were analyzed for pesticide residues can be seen in **Table 18B.** It is apparent that the size parameters are limited due to the selective sampling methods.

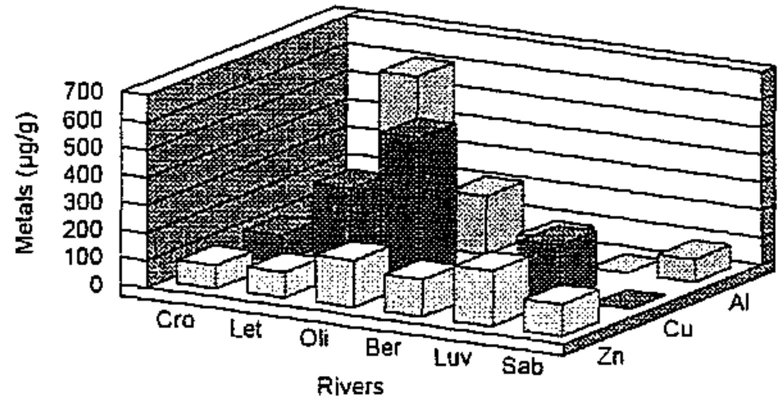


Figure 16: The mean of the body loads for aluminium, copper and zinc in all the fish species analyzed per river.

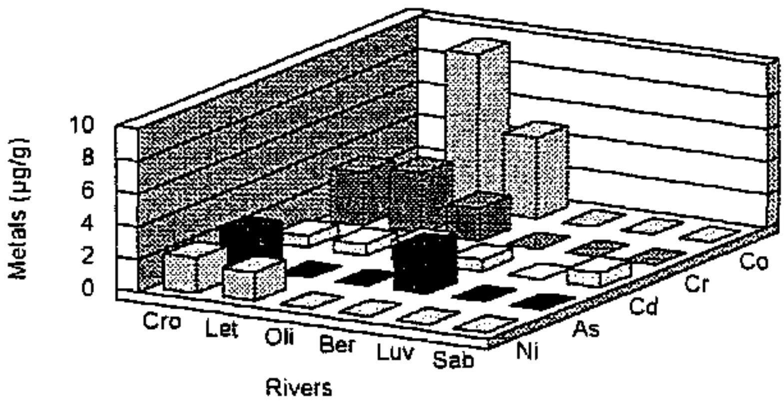


Figure 17: The mean of the body loads for arsenic, cadmium, chrome, cobalt and nickel in all the fish species analyzed per river.

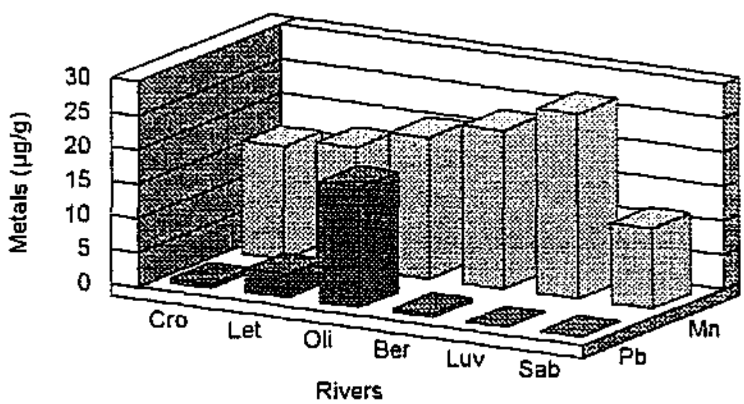


Figure 18: The mean of the body loads for lead and manganese in all the fish species analyzed per river.

4.7.1 Pesticides concentrations in fish tissue

Appendix D1 indicates the mean pesticide loads per tissue by combining all the species of fish in the rivers sampled.

The following null hypothesis is tested:
The levels of the specified pesticides in different tissues do not represent populations with the same medians.

The null hypothesis is rejected for Lindane, Heptachlor, Endosulfan, Mercapthion Pirimiphos and Atrazine on the 95% confidence limit. The null hypothesis is accepted for BHC, Dieldrin, DDE, DDD, DDT, Aldrin and Diazinon, indicating that the distribution of values for these pesticides have different medians for the tissues (**Table 29**).

Table 29: Kruskall Wallis analysis of variance between tissues for selected pesticides.

Sites	Pesticide	Sample size	df	H	p
All [#]	BHC	375	7	20.993	0.004
All [#]	Dieldrin	375	7	29.793	**0.000**
All [#]	Lindane	375	7	3.743	0.809
All [#]	DDE	375	7	110.716	**0.000**
All [#]	DDD	375	7	104.480	**0.000**
All [#]	DDT	375	7	93.128	**0.000**
All [#]	Heptachlor	375	7	12.182	0.095
All [#]	Endosulfan	375	7	7.155	0.413
All [#]	Mercapthion	375	7	8.761	0.270
All [#]	Diazinon	375	7	79.123	**0.000**
All [#]	Pirimiphos	375	7	7.832	0.348
All [#]	Aldrin	375	7	22.421	0.002
All [#]	Atrazine	375	7	13.778	0.055

[#] Tissues : Ovaries, Fat, Testes, Liver, Flesh, Gut, Whole

Appendix D1 indicates the pesticide loads per tissue of the fish analyzed for all the rivers combined. From this table the tissues are ranked according to the three with the highest pesticide levels (Table 30).

Table 30: A ranking of the highest pesticide concentrations in the fish tissues.

Pesticides	Tissues					
	Ovaries	Fat	Testes	Liver	Flesh	Gut
BHC		xx	xxx	x		
Lindane		xx	x			xxx
Dieldrin		x		xxx	xx	
DDE		xxx		x		xx
DDD		xxx	x			xx
DDT	x	xxx				xx
Diazianon		xx	x		xxx	
Endosulfan		x		xx		xxx
Mercapthion	x			xx	xxx	
Pirimos		xxx		xx		
Aldrin						xxx
Atrazine		xxx	xx	xx		

Where: xxx = highest mean value detected, xx = second highest mean value detected, x = third highest mean value detected.

The gut values were intestine removed from *L. rosae*. This intestine included the intestine contents, intestinal tissue and internal intestinal fat which contributed a largely to the weight of these gut samples.

The mean pesticide values in the tissues varied considerably from tissue to tissue. The maximum mean pesticide value in a tissue and the range per pesticide are indicated below (**Appendix D1**) :

BHC = 0.0137 μg/g in testes (range 0.0005 to 0.320 μ/g),
Dieldrin = 0.0045 μg/g in liver (range 0.0005 to 0.120 μ/g),
Lindane = 1.17 μg/g in gut (range 0.0004 to 11.59 μ/g),
DDE = 0.929 μg/g in fat (range 0.0008 to 5.45 μ/g),
DDD = 1.40 μg/g in fat (range 0.002 to 18.04 μ/g),
DDT = 1.04 μg/g in fat (range 0.002 to 15.04 μ/g),
Heptachlor = 0.006 μg/g in liver (range 0.005 to 0.045 μ/g),
Endosulfan = 0.373 μg/g in gut (range 0.001 to 7.35 μ/g),
Mercapthion = 0.100 μg/g in flesh (range 0.005 to 0.100 μ/g),

Diazinon = 0.019 μg/g in flesh (range 0.005 to 0.020 μ/g),

Pirimiphos =0.012 μg/g in fat (range 0.005 to 0.430 μ/g),

Aldrin = 0.043 μg/g in gut (range 0.005 to 0.580 μ/g),

Atrazine = 0.009 μg/g in fat (range 0.0005 to 0.110 μ/g).

4.7.2 Pesticides loads between species of fish

Appendix D2 indicates the mean body loads of the pesticides per species of fish (rivers combined, N >3). There is a large variation in the mean pesticide concentrations between the species of fish.

The following null hypothesis is tested: *The levels of the specified pesticides in different species do not represent populations with the same medians.*

The null hypothesis is rejected for Lindane, Heptachlor, Pirimiphos, Aldrin and Mercapthion on the 95% confidence limit. The null hypothesis is accepted for BHC, Dieldrin, DDE, DDD, DDT, Endosulfan, Diazinon, and Atrazine, indicating that the distribution of values for these pesticides have different medians for the species (**Table 31**).

Table 31: Kruskall Wallis analysis of variance between species for selected pesticides.

Sites	Pesticide	Sample size	df	H	p
All #	BHC	375	9	25.258	**0.003**
All #	Dieldrin	375	9	22.830	**0.007**
All #	Lindane	375	9	12.351	0.194
All #	DDE	375	9	22.200	**0.008**
All #	DDD	375	9	27.261	**0.001**
All #	DDT	375	9	34.043	**0.000**
All #	Heptachlor	375	9	11.140	0.266
All #	Endosulfan	375	9	22.002	**0.009**
All #	Mercapthion	375	9	12.367	0.193
All #	Diazinon	375	9	18.759	**0.027**
All #	Pirimiphos	375	9	4.633	0.865
All #	Aldrin	375	9	4.257	0.894
All #	Atrazine	375	9	85.155	**0.000**

Species : Om, Cc, Lm, Bm, Hv, C, Lr, Tr, Lc, Sd

The following is a synthesis of the species of fish studied with the highest metal body loads and range (**Appendix D2**) :

BHC = 0.039 μg/g in *L. congoro* (range 0.0005 to 0.320 μ/g),
Dieldrin = 0.013 μg/g in *H. vittatus* (range 0.005 to 0.120 μ/g),
Lindane = 0.892 μg/g in *L. molybdinus* (range 0.005 to 17.27 μ/g),
DDE = 0.826 μg/g in *L. rosae* (range 0.005 to 5.45 μ/g),
DDD = 0.897 μg/g in *C. gariepinus* (range 0.005 to 18.07 μ/g),
DDT = 0.918 μg/g in *H. vittatus* (range 0.005 to 15.04 μ/g),
Heptachlor = 0.007 μg/g in *L. rosae* (range 0.005 to 0.045 μ/g),
Endosulfan = 0.657 μg/g in *L. molybdinus* (range 0.005 to 7.35 μ/g),
Mercapthion = 0.010 μg/g in *T. rendalli* (range 0.005 to 0.100 μ/g),
Diazinon = 0.028 μg/g in *T. rendalli* (range 0.005 to 0.200 μ/g),
Pirimiphos = 0.027 μg/g in *T. rendalli* (range 0.005 to 0.430 μ/g),
Aldrin = 0.013 μg/g *O. mossambicus* in (range 0.005 to 0.580 μ/g),
Atrazine = 0.018 μg/g in *C. carpio* (range 0.0005 to 0.820 μ/g),

Table 32 ranks the three highest mean pesticide loads per species values recorded per pesticide (only species of n ≥ 3 were included).

4.7.3 Pesticide concentrations between tissues per species

Figure 19a and **Figure 19b** (**Appendix D3**) indicates the combined metal loads per species of fish and per tissue. This table indicates the tissues responsible for the highest pesticide loads in the specific species of fish. In order of priority, from highest to lowest, the species with the highest body pesticide loads are (**Appendix D3**).

L. molybdinus, C. gariepinus, H. vittatus, L. rosae, O. mossambicus and *B. marequensis.*

These six highest ranked species of fish are commented on below.

L. molybdinus

Fatty tissues; ovaries (BHC - 0.005 μg/g), fat (dieldrin 11.59 μg/g, n=1), testes (DDD 0.278 μg/g), and liver: DDE (0.358 μg/g), heptachlor (0.008 μg/g), endosulfan (3.37 μg/g), mercapthion (0.018 μg/g), diazinon (0.024 μg/g), pirimiphos (0.026 μg/g) were responsible for the high pesticide loads in this species (**Figure 19a**, **Figure 19b**).

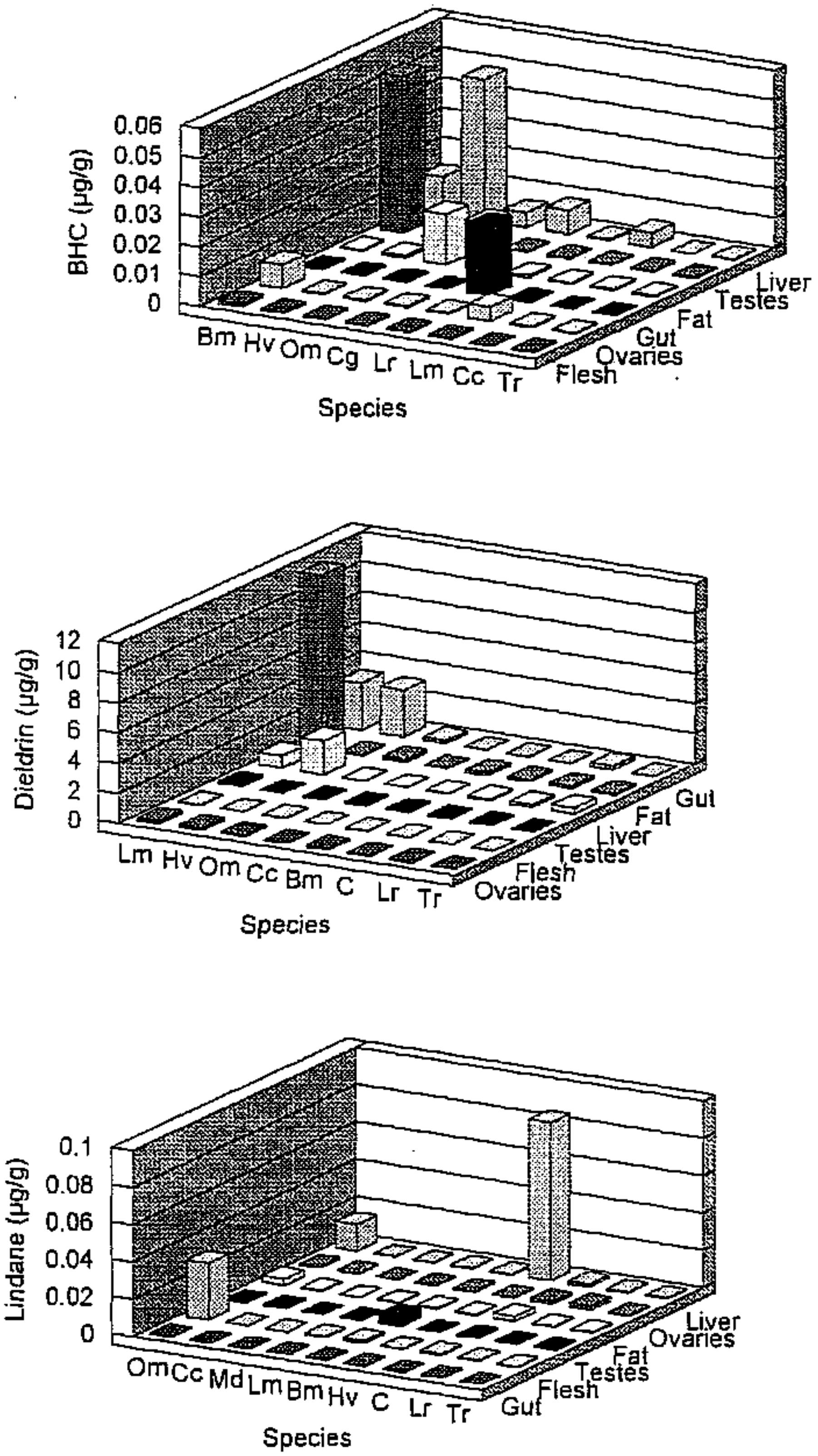


Figure 19a: Mean BHC, Dieldrin and Lindane levels in fish tissues from different species.

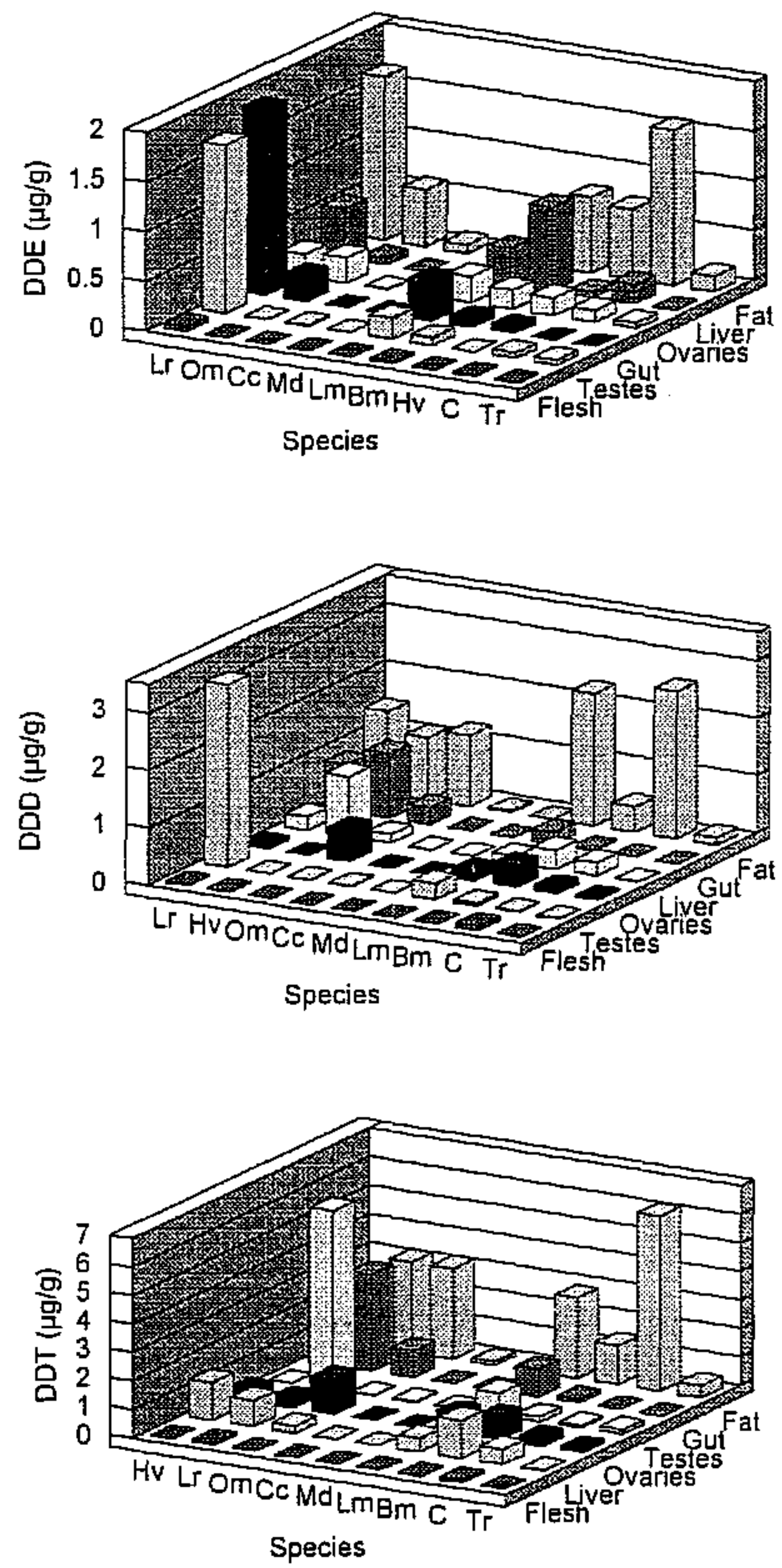


Figure 19b: Mean DDE, DDD and DDT levels in fish tissues from different species.

Table 32: The highest mean pesticide values recorded per species of fish (all rivers combined).

	Species									
Pesticides	**Om**	**Cc**	**Lm**	**Bm**	**Si**	**Hv**	**Cg**	**Lr**	**Tr**	**Lc**
BHC				xx		x	x			xxx
Lindane			xxx			xx	x			
Dieldrin	xx					xxx				x
DDE						x	xx	xxx		
DDD						xx	xxx	x		
DDT	x					xxx	xx			
Diazianon			xx	x					xxx	
Endosulfan			xxx	xx			xx			
Mercapthion			xx				x		xxx	
Pirimos	x		xx						xxx	
Aldrin	xxx									
Heptachlor			xx					xxx		
Atrazine	xx	xxx								

Where: xxx = highest mean value detected, xx = second highest mean value detected, x = third highest mean value detected.

C. gariepinus

Fatty tissues; fat (BHC - 0.015 μg/g), testes (dieldrin 0.166 μg/g), fat (lindane 0.003 μg/g), fat (DDD 2.48 μg/g), fat (DDE 1.48 μg/g), fat (DDT 1.81 μg/g) were responsible for the high pesticide loads in this species (**Figure 19a**, **Figure 19b**).

H. vittatus

Fatty tissues; gut (dieldrin 3.12 μg/g) fat (DDD 0.775 μg/g), ovaries (DDE 1.081 μg/g), ovaries (DDT 1.81 μg/g); and liver (BHC - 0.048 μg/g and lindane 0.085 μg/g) were responsible for the high pesticide loads in this species (**Figure 19a**, **Figure 19b**).

L. rosae

Fatty tissues; fat (BHC - 0.0008 μg/g, DDD - 1.43 μg/g, DDE - 1.65 μg/g), testes (DDT 0.694 μg/g and DDD 1.62 μg/g) and liver (lindane 0.118 μg/g) were responsible for the high pesticide loads in this species (**Figure 19a**, **Figure 19b**).

O. mossambicus

Fatty tissues: fat (BHC - 0.012 μg/g, DDD - 0.943 μg/g, DDE - 0.58 μg/g, DDT - 0.979, diazinon - 0.0074 μg/g, pirimiphos - 0.0087 μg/g, atrazine - 0.03 μg/g); liver (dieldrin 0.178 μg/g) and flesh (lindane - 0.30 μg/g) were responsible for the high pesticide loads in this species (**Figure 19a, Figure 19b**).

B. marequensis

Fatty tissues: testes (BHC - 0.053 μg/g, lindane - 0.0054 μg/g), fat (dieldrin - 11.59 μg/g, DDD 0.442 μg/g), ovaries (DDT - 0.216 μg/g); and liver (DDE - 0.842 μg/g, endosulfan - 0.63 μg/g, diazinon - 0.011 μg/g) were responsible for the high pesticide loads in this species (**Figure 19a, Figure 19b**).

From the analysis above it indicates that the following tissues have consistently higher pesticides in the species of fish analyses irrespective of river:

fatty tissues (fat, testes, ovaries), and liver.

4.7.4 Fish pesticide loads in each river

The mean (standard deviation and range) of the combined fish tissues per river are indicated in **Figure 20a** to **Figure 20d (Appendix D4)**. The following null hypothesis is tested:

The levels of the specified pesticides in different rivers do not represent populations with the same medians.

The null hypothesis is rejected for Lindane, Heptachlor, Mercapthion, Pirimiphos and Aldrin on the 95% confidence limit. The null hypothesis is accepted for BHC, Dieldrin, DDE, DDD, DDT, Endosulfan, Diazinon and Atrazine, indicating that the distribution of values for these pesticides have significantly different medians for the different rivers (**Table 33**).

Table 33: Kruskall Wallis analysis of variance between rivers for selected pesticides.

Rivers	Pesticide	Sample size	df	H	p
Ber. Cro. Let. Lev. Oli. Sab	BHC	378	5	37.610	**0.000**
Ber. Cro. Let. Lev. Oli. Sab	Dieldrin	378	5	21.733	**0.001**
Ber. Cro. Let. Lev. Oli. Sab	Lindane	378	5	6.632	0.250
Ber. Cro. Let. Lev. Oli. Sab	DDE	378	5	80.409	**0.000**
Ber. Cro. Let. Lev. Oli. Sab	DDD	378	5	146.311	**0.000**
Ber. Cro. Let. Lev. Oli. Sab	DDT	378	5	141.132	**0.000**
Ber. Cro. Let. Lev. Oli. Sab	Heptachlor	378	5	2.045	0.843
Ber. Cro. Let. Lev. Oli. Sab	Endosulfan	378	5	31.920	**0.000**
Ber. Cro. Let. Lev. Oli. Sab	Mercapthion	378	5	4.116	0.533
Ber. Cro. Let. Lev. Oli. Sab	Diazinon	378	5	36.732	**0.000**
Ber. Cro. Let. Lev. Oli. Sab	Pirimiphos	378	5	5.160	0.397
Ber. Cro. Let. Lev. Oli. Sab	Aldrin	378	5	1.021	0.961
Ber. Cro. Let. Lev. Oli. Sab	Atrazine	378	5	134.386	**0.000**

The mean pesticide values detected in the lumped fish tissues per river indicate the following order of pesticide loads per river (**Table 33** and **Figure 20a** to **Figure 20d**):

BHC : Crocodile (0.0094 μg/g) > Letaba (0.0072 μg/g) > Olifants (0.0057 μg/g) > Sabie (0.0008 μg/g) > Luvuvhu and Berg (0.0006 μg/g)

Dieldrin: Crocodile (0.2662 μg/g) > Letaba (0.1973 μg/g) > Olifants (0.0735 μg/g) > Berg (0.0343 μg/g) > Sabie (0.0248 μg/g) > Luvuvhu (0.015 μg/g)

Lindane: Crocodile (0.0029 μg/g) > Letaba (0.0016 μg/g), with traces amounts in the other rivers

DDD: Letaba (1.73 μg/g) > Luvuvhu (1.009 μg/g) > Sabie (0.640 μg/g) > Olifants (0.283 μg/g)> Crocodile (0.163 μg/g) > Berg (0.0452 μg/g)

DDE :	Letaba (0.955 μg/g) > Luvuvhu (0.516 μg/g) > Olifants (0.361 μg/g) > Sabie (0.2979 μg/g) > Crocodile (0.235 μg/g) > Berg (0.0473 μg/g)
DDT :	Letaba (1.34 μg/g) > Olifants (0.304 μg/g) > Luvuvhu (0.238 μg/g) > Crocodile (0.120 μg/g) > Sabie (0.120 μg/g) > Berg (0.0083 μg/g)
Heptachlor:	Crocodile River (0.0053 μg/g) > traces in the other rivers
Endosulfan:	Crocodile River (0.2291 μg/g) > traces in the other rivers
Mercapthion:	Crocodile River (0.0068 μg/g) > traces in the other rivers
Diazinion:	Crocodile River (0.013 μg/g)> traces in the other rivers
Pirimiphos:	Crocodile River (0.0093 μg/g) > traces in the other rivers
Aldrin :	Crocodile River (0.0081 μg/g) > traces in the other rivers
Endrin :	Traces detected in all rivers
Atrazine:	Berg River (0.015 μg/g), traces in other rivers only.

4.7.5 Comparison of the fish pesticide loads between site in each river

Appendix D5 indicates the pesticide body loads per site in each river for the fish analyzed and the statistics between sites per river. Trends per river for the pesticide values were compared between sites form the highest upstream sire to the lowest downstream site. High pesticide values per site could also indicate point or diffuse sources of pollution.

The following null hypothesis is tested for each river:
The levels of the specified pesticides at different sites do not represent populations with the same medians.

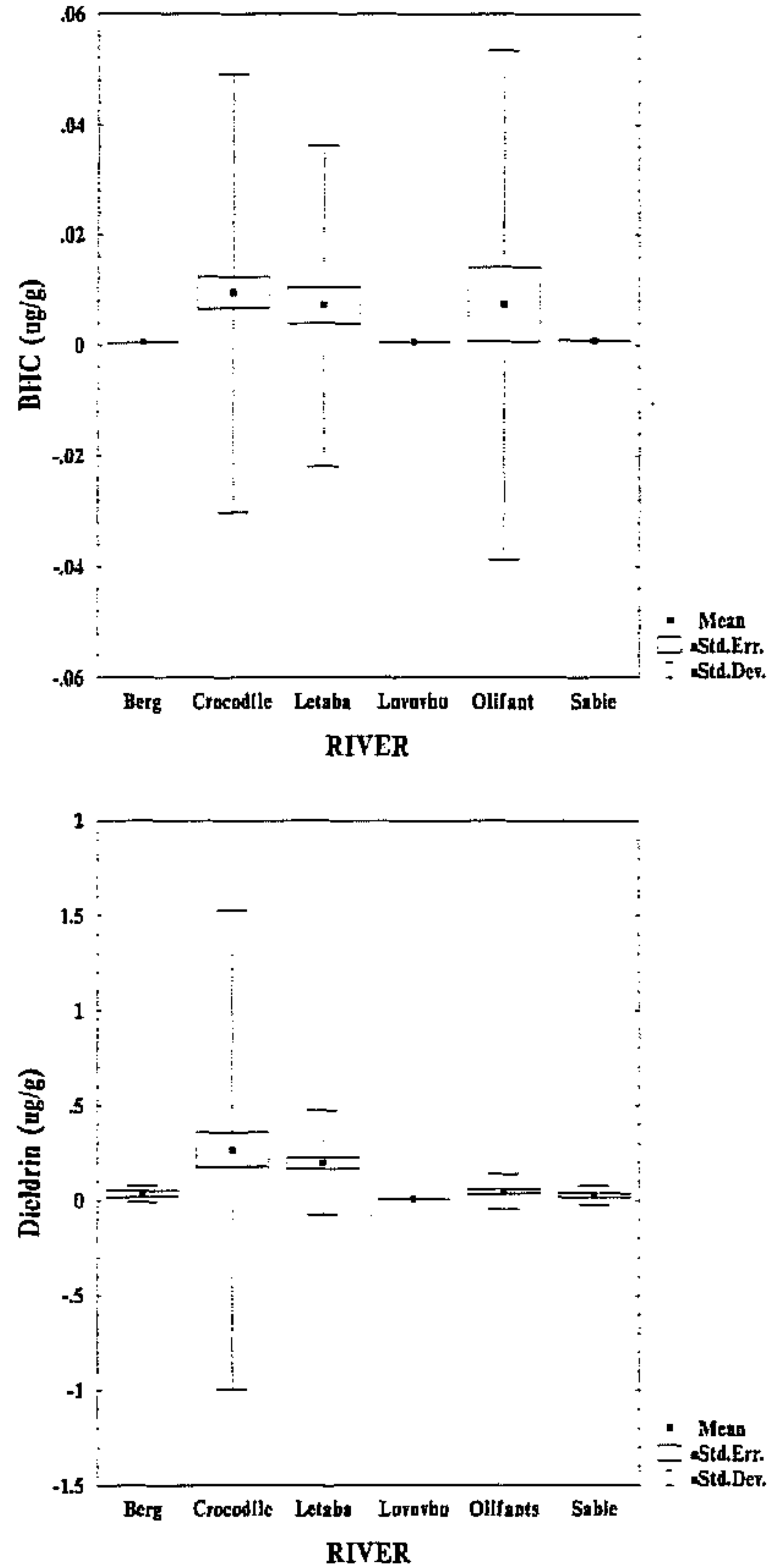


Figure 20a: **Means, standard deviation and outliers for BHC and dieldrin levels in fish tissues for different rivers.**

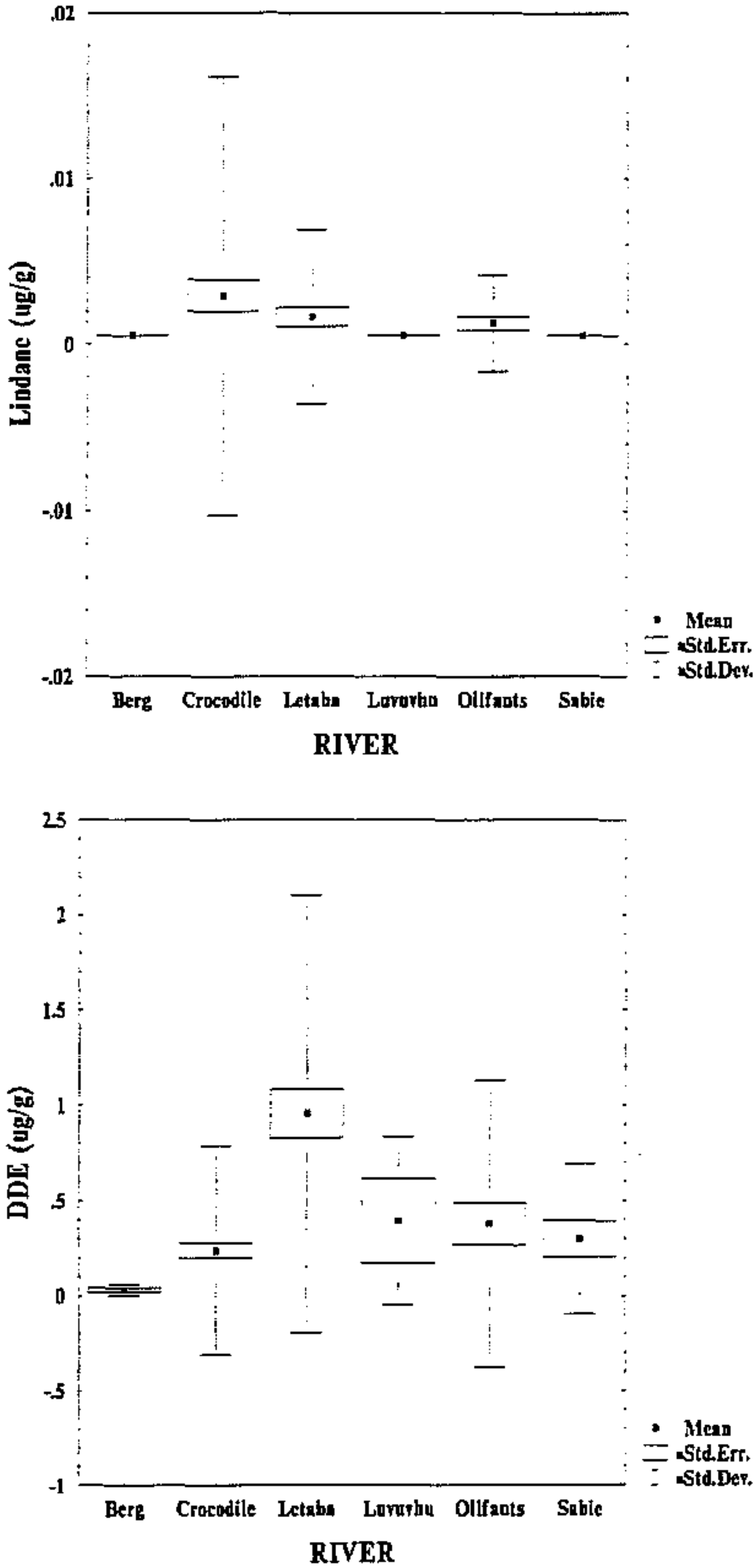
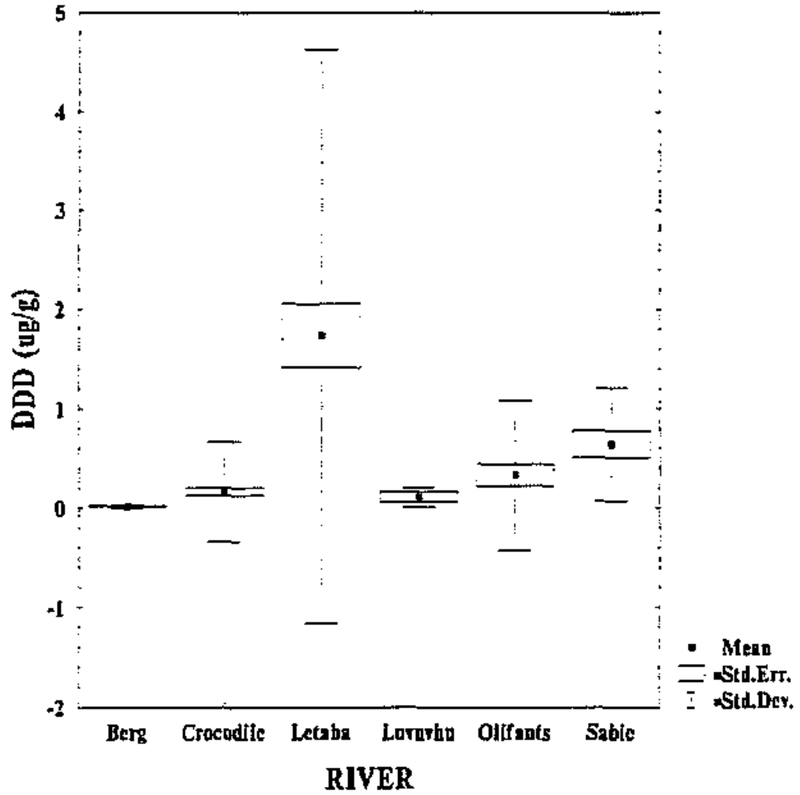


Figure 20b: Mean (+SD) and outliers for lindane & DDE levels in fish tissues in rivers.



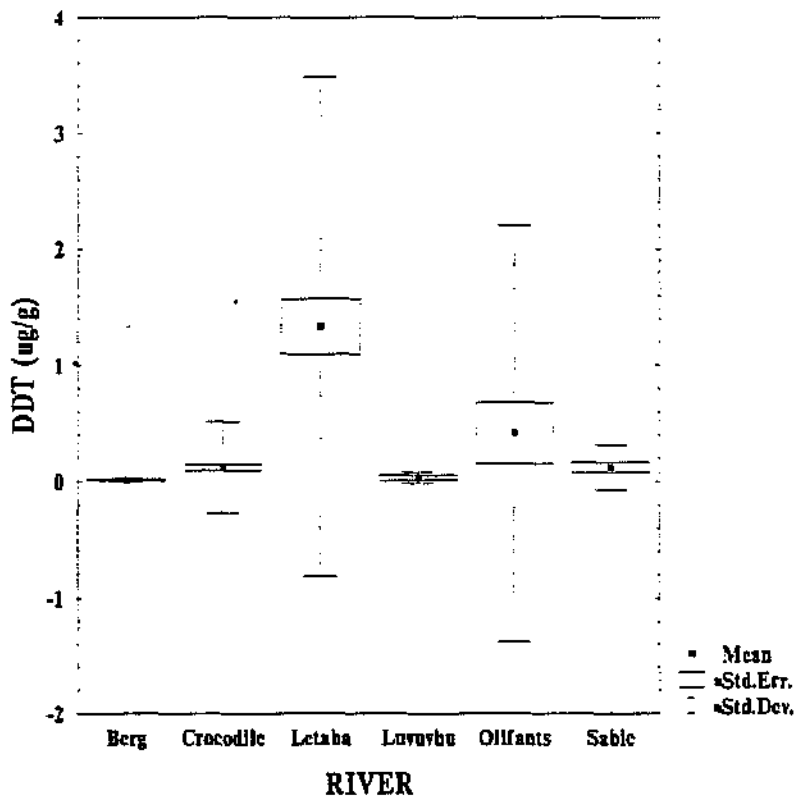


Figure 20c : **Means, standard deviation and outliers for DDD and DDT levels in fish tissues for different rivers.**

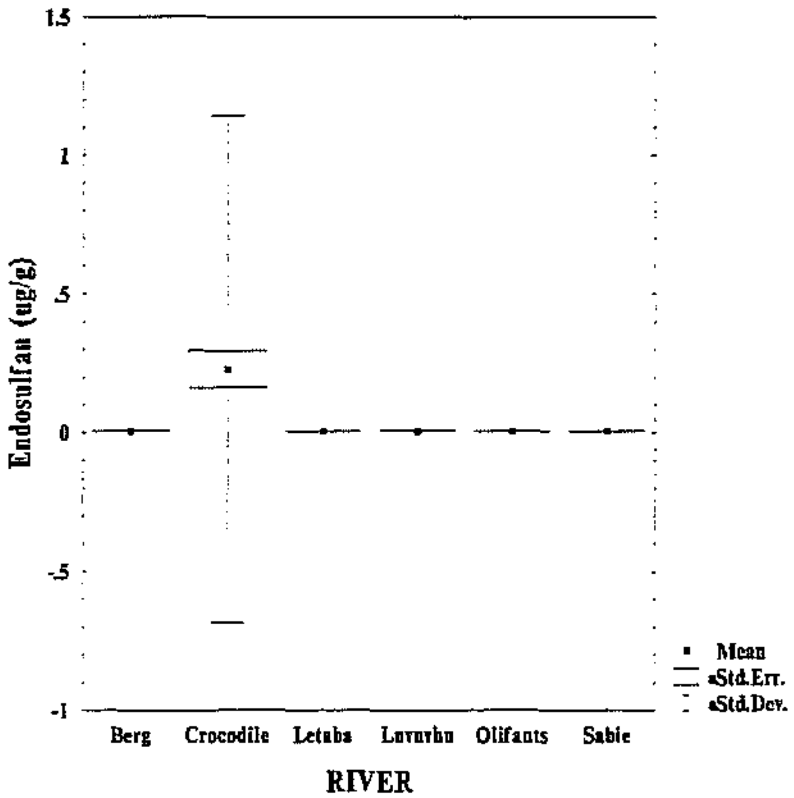


Figure 20d : **Means, standard deviation and outliers for endosulfan levels in fish tissues for different rivers.**

4.7.5.1 Berg River

The limited pesticide values detected at both sites in the Berg River indicate that the sites are similar with respect to low pesticide values (**Appendix D5**).

The null hypothesis is rejected for the Berg river sites for all pesticides on the 95% confidence limit, indicating that the distribution of values for all pesticides have similar medians for the two sites (**Table 34**).

Table 34: Kruskall Wallis analysis of variance between sites for selected pesticides in the Berg River.

Sites	Pesticide	Sample size	df	H	p
Misverst, Voelvlei	BHC	19	1	1.375	0.241
Misverst, Voelvlei	Dieldrin	19	1	0.213	0.644
Misverst, Voelvlei	Lindane	19	1	0.000*	1
Misverst, Voelvlei	DDE	19	1	1.341	0.247
Misverst, Voelvlei	DDD	19	1	0.143	0.705
Misverst, Voelvlei	DDT	19	1	0.214	0.643
Misverst, Voelvlei	Heptachlor	19	1	0.000*	1
Misverst, Voelvlei	Endosulfan	19	1	0.000*	1
Misverst, Voelvlei	Mercapthion	19	1	0.000*	1
Misverst, Voelvlei	Diazinon	19	1	0.000*	1
Misverst, Voelvlei	Pirimiphos	19	1	0.000*	1
Misverst, Voelvlei	Aldrin	19	1	0.000*	1
Misverst, Voelvlei	Atrazine	19	1	0.146	0.703

* No variability

4.7.5.2 Crocodile River

BHC : Values low, increasing downstream from Crocodile Hotel (0.016 μg/g) to Riverside (0.026 μg/g) and decreasing to Tenbosch (0.0020 μg/g).

Lindane : Values increase from Crocodile Hotel (0.076 μg/g) to Nelspruit, where the values decrease, and then increasing downstream to Riverside (0.856 μg/g).

Dieldrin : Values increase from Crocodile Hotel (0.0019 μg/g) to Nelspruit, where values decrease, then increase down the rest of the river to Tenbosch (0.0063 μg/g).

DDE : Values increase to Nelspruit, decrease at Angling Club (0.243 μg/g) and the remain similar with the highest values recorded at Riverside Farm (0.327 μg/g).

DDD : Values increase to Crocodile Hotel (0.429 μg/g) thereafter lower values down the rest of the river.

DDT : Values increase to Nelspruit, are reduced to Lions Club thereafter in creasing down the rest of the length of the river. The highest values were recorded at Crocodile Hotel (0.276 μg/g).

Heptachlor : Values were only clearly detected at Mataffin (0.0055 μg/g) and Tenbosch (0.0058 μg/g) weirs.

Endosulfan : Values increased from Crocodile Hotel (0.0068 μg/g) to a maximum value at Mataffin weir (0.592 μg/g), decreased values around Nelspruit, increased values at Riverside Farm(0.2572 μg/g) and reduced values at Tenbosch weir (0.050 μg/g).

Mercapthion : Values were only clearly detected at Riverside Farm (0.0147 μg/g).

Diazinon : Values increased down the length of the Crocodile River to Tenbosch (0.0167 μg/g).

Pirimiphos : Values increased down the length of the Crocodile River to Tenbosch (0.0152 μg/g).

Aldrin : Values were only clearly detected at the lowest site (Tenbosch - 0.0158 μg/g).

Endrin : Values were low down the length of the river.

The null hypothesis is rejected for the Crocodile river sites for BHC, Dieldrin, Lindane, DDE, DDD, DDT, Heptachlor, Pirimiphos, Aldrin and Atrazine on the 95% confidence limit. The null hypothesis is accepted for Endosulfan, Mercapthion and Diazinon indicating that the distribution of values for these pesticides have different medians for the sites (Table 35).

Table 35: Kruskall Wallis analysis of variance between sites for selected pesticides in the Crocodile River.

Sites	Pesticide	Sample size	df	H	p
All #	BHC	187	7	11.279	0.127
All #	Dieldrin	187	7	1.399	0.986
All #	Lindane	187	7	2.272	0.943
All #	DDE	187	7	3.621	0.822
All #	DDD	187	7	10.390	0.168
All #	DDT	187	7	8.914	0.259
All #	Heptachlor	187	7	3.657	0.818
All #	Endosulfan	187	7	17.884	**0.013**
All #	Mercapthion	187	7	18.293	**0.011**
All #	Diazinon	187	7	19.498	**0.007**
All #	Pirimiphos	187	7	2.397	0.935
All #	Aldrin	187	7	2.529	0.925
All #	Atrazine	187	7	0.000*	1

* No variability
# Sites: Hngel_cl, Mataffin, Rverside, Tenbosch, Montrose, Croc_hot, Lions_cl, Rvuletts

4.7.5.3. Letaba River

The following observations is a synthesis of Appendix D5.

BHC values were similar at the upstream sites (Junction, Pump & Prieska) and lower at the downstream sites.

Lindane values were similar at the upstream sites (Junction - 0.020 μg/g, Pump - 0.011 μg/g and Prieska - 0.020 μg/g) and lower at the downstream sites (Engelhardt - 0.156 μg/g).

Dieldrin values were higher at the upstream sites (Junction - 0.0037 μg/g) then decreasing after the Slab (0.0008 μg/g).

DDE values increased down the Letaba River until the Slab (1.14 μg/g), thereafter decreasing. Hudson Ntsanwisi Dam (2.00 μg/g) had the highest value recorded in the Letaba River catchment.

DDD values increased down the Letaba River until the Slab (2.93 μg/g), thereafter decreasing down the length of the river.

DDT values increased down the Letaba River until the Slab (2.66 μg/g), thereafter decreasing down the length of the river.

Heptachlor, Endosulfan, Mercapthion, Diazinon, Pirimiphos, Aldrin and Endrin values were low throughout the Letaba catchment (**Appendix D5**).

The null hypothesis is rejected for the Letaba river sites for Dieldrin, Lindane, DDE, DDD, DDT, Heptachlor, Pirimiphos, Aldrin, Atrazine, Endosulfan, Mercapthion and Diazinon on the 95% confidence limit. The null hypothesis is accepted for BHC indicating that the distribution of values for BHC have different medians for the sites (**Table 36**).

4.7.5.4. Olifants River

The null hypothesis is rejected for the Olifants river sites for Lindane, Heptachlor, Pirimiphos, Aldrin, Atrazine, Endosulfan, Mercapthion and Diazinon on the 95% confidence limit. The null hypothesis is accepted for BHC, Dieldrin, DDE, DDD and DDT indicating that the distribution of values for these pesticides have different medians for the sites (**Table 37**).

The following observations is a synthesis of **Appendix D5**.

BHC values were low in the Olifants River with the two dam sites being the highest (Arabie 0.0012 μg/g and Loskop - 0.054 μg/g dams).

Lindane values were relatively low in the Olifants River with the two dam sites being the highest (Arabie - 0.144 μg/g and Loskop - 0.166 μg/g dams) and Baluli the highest in the lower Olifants

Dieldrin values were relatively low in the Olifants River with the following sites having the highest values (Arabie- 0.0008 μg/g, Loskop - 0.0005 μg/g, Baluli - 0.0018 μg/g and Mamba - 0.0012 μg/g).

DDE value indicated that the area around the Selati River (0.069 μg/g) confluence with the Olifants down to Meetwal (0.607 μg/g) had the highest tissue values.

Table 36: Kruskall Wallis analysis of variance between sites for selected pesticides in the Letaba River.

Sites	Pesticide	Sample size	df	H	p
All #	BHC	81	8	33.084	**0.000**
All #	Dieldrin	81	8	11.111	0.196
All #	Lindane	81	8	2.229	0.973
All #	DDE	81	8	4.549	0.805
All #	DDD	81	8	11.702	0.165
All #	DDT	81	8	12.996	0.112
All #	Heptachlor	81	8	0.000*	1
All #	Endosulfan	81	8	0.000*	1
All #	Mercapthion	81	8	0.000*	1
All #	Diazinon	81	8	0.000*	1
All #	Pirimiphos	81	8	0.000*	1
All #	Aldrin	81	8	0.000*	1
All #	Atrazine	81	8	0.000*	1

* No variability # Sites: Junction, Prieska, Pump_sta, Slab, Englhrdt, Prieska_F, Ranch16, Huson, Midlet

Table 37: Kruskall Wallis analysis of variance between sites for selected pesticides in the Olifants River.

Sites	Pesticide	Sample size	df	H	p
All #	BHC	64	9	25.718	**0.002**
All #	Dieldrin	64	9	29.452	**0.001**
All #	Lindane	64	9	13.685	0.134
All #	DDE	64	9	21.760	**0.010**
All #	DDD	64	9	25.384	**0.003**
All #	DDT	64	9	27.527	**0.001**
All #	Heptachlor	64	9	0.000*	1
All #	Endosulfan	64	9	0.000*	1
All #	Mercapthion	64	9	0.000*	1
All #	Diazinon	64	9	0.000*	1
All #	Pirimiphos	64	9	0.000*	1
All #	Aldrin	64	9	0.000*	1
All #	Atrazine	64	9	0.000*	1

* No variability # Sites: Loskop, Baluli, Mamba_wr, Selati, Preselat, Prneef_D, Pstselat, Klipsprt, Meetwal, Arabie

DDD values were highest at Meetwal (1.00 μg/g) and there was at trend of higher values in the Kruger National Park.

DDT values indicated that Mamba Weir (1.29 μg/g) had the highest values.

Heptachlor, Endosulfan, Mercapthion, Diazinon, Pirimiphos, Aldrin and Endrin values were low throughout the Olifants River sites sampled.

Pieneefs Dam's pesticide values were all below the level of detection indicating that no detectable pesticide contamination exists in this dam. No contamination is expected as the catchment draining into this dam is solely in the Kruger National Park.

4.7.5.5. Luvuvhu River

The null hypothesis is rejected for the Luvuvhu river sites for BHC, Dieldrin, Lindane, DDE, DDD and DDT. Heptachlor, Pirimiphos, Aldrin, Atrazine, Endosulfan, Mercapthion and Diazinon on the 95% confidence limit. The distribution of values for pesticides thus have similar medians for the sites (**Table 38**).

The following observations is a synthesis of **Appendix D5**.

BHC values were similar and low at the sites sampled (range 0.0005 to 0.001 μg/g).

Lindane values were low and recorded at the Farm (0.023 μg/g) and Mkunya (0.016 μg/g) sites only.

Dieldrin values were at the level of detection at all sites.

DDE values increased down the length of the river (Farm 0.165 μg/g, Mkayadu 1.37 μg/g).

DDD values were highest at the Settlement (5.84 μg/g) and Mkunya (1.28 μg/g sites).

DDT value were highest at the Mkunya (1.40 μg/g) site.
Heptachlor, Endosulfan, Mercapthion, Diazinon, Pirimiphos, Aldrin and Endrin values were low in the Luvuvhu River.

Table 38: Kruskall Wallis analysis of variance between sites for selected pesticides in the Luvuvhu River.

Sites	Pesticide	Sample size	df	H	p
All [#]	BHC	8	3	1.167	0.761
All [#]	Dieldrin	8	3	0.911	0.823
All [#]	Lindane	8	3	0.000*	1
All [#]	DDE	8	3	4.333	0.228
All [#]	DDD	8	3	4.639	0.200
All [#]	DDT	8	3	4.419	0.220
All [#]	Heptachlor	8	3	0.000*	1
All [#]	Endosulfan	8	3	0.000*	1
All [#]	Mercapthion	8	3	0.000*	1
All [#]	Diazinon	8	3	0.000*	1
All [#]	Pirimiphos	8	3	0.000*	1
All [#]	Aldrin	8	3	0.000*	1
All [#]	Atrazine	8	3	0.000*	1

* No variability   # Sites: Farm, Mkyaupst, Settlmnt, Mkyadnst

4.7.5.6 Sabie River

The following observations is a synthesis of **Appendix D5.**

At the single site sampled the following pesticides were recorded; BHC, Lindane, Dieldrin, DDE, DDD, DDT

Heptachlor, Endosulfan, Mercapthion, Diazinon, Pirimiphos, Aldrin and Endrin values were low in the Sabie River.

4.7.6 Pesticide loads of species of fish per river

Appendix D6 indicates the pesticide loads per species of fish in each river. The following species of fish had the highest mean pesticide loads per river sampled.

4.7.6.1 Berg River

BHC : *C. carpio* (0.0006 μg/g).

Lindane: *O. mossambicus* (0.037 μg/g) > *C. carpio* (0.035 μg/g) > *M. dolomieu* (0.0050 μg/g)

DDE : *O. mossambicus* (0.076 μg/g) > *C. carpio* (0.039 μg/g) > *M. dolomieu* (0.020 μg/g)

DDD : *M. dolomieu* (0.150 μg/g) > *O. mossambicus* (0.047 μg/g) > *C. carpio* (0.031 μg/g)

DDT : *C. carpio* (0.0101 μg/g) > *O. mossambicus* (0.007 μg/g) > *M. dolomieu* (0.0050 μg/g)

Atrazine: *O. mossambicus* (0.115 μg/g) > *C. carpio* (0.020 μg/g) > *M. dolomieu* (0.0005 μg/g)

4.7.6.2 Crocodile River

BHC : *L. congoro* (0.047 μg/g) > *C. gariepinus* (0.013 μg/g) > *B. marequensis* (0.011 μg/g)

Lindane: *H. vittatus* (1.12 μg/g) > *L. molybdinus* (1.07 μg/g)> *L. congoro* (0.139 μg/g)

Dieldrin: *H. vittatus* (0.071 μg/g) > *O. mossambicus* (0.012 μg/g) > *L. congoro* (0.0029 μg/g)

DDE : *B. marequensis* (0.350 μg/g) > *L. rosae* (0.336 μg/g) > *L. congoro* (0.189 μg/g)

DDD : *H. vittatus* (0.550 μg/g)> *B. marequensis* (0.233 μg/g) > *C. gariepinus*

(0.184 µg/g)

DDT : *H. vittatus*(0.933 µg/g) > *B. marequensis* (0.144 µg/g) > *C. gariepinus* (0.106 µg/g)

Endosulfan: *L. molybdinus* (0.820 µg/g) > *B. marequensis* (0.226 µg/g) > *L. rosae* (0.145 µg/g)

Mercapthion: *L. molybdinus* = *T. rendalli* (0.010 µg/g) > *C. gariepinus* (0.0067 µg/g)

Diazinon: *T. rendalli* (0.028 µg/g) > *C. gariepinus* (0.013 µg/g) > *O. mossambicus* (0.0126 µg/g)

Pirimiphos: *T. rendalli* (0.027 µg/g) > *O. mossambicus* (0.011 µg/g) > *C. gariepinus* (0.0081 µg/g)

4.7.6.3 Letaba River

BHC : *L. rosae* (0.015 µg/g) > *L. molybdinus* (0.011 µg/g) > *C. gariepinus* (0.0047 µg/g)

Dieldrin: *L. rosae* (0.455 µg/g) > *B. marequensis* (0.346 µg/g) > *C. gariepinus* (0.181 µg/g)

Lindane: *O. mossambicus* (0.0024 µg/g) > *C. gariepinus* (0.0016 µg/g)

DDE : *L. rosae* (3.10 µg/g) > *C. gariepinus* (1.33 µg/g) > *B. marequensis* (0.990 µg/g)

DDD : *C. gariepinus* (3.03 µg/g) > *L. rosae* (2.80 µg/g) > *O. mossambicus* (1.18 µg/g)

DDT : *C. gariepinus* (2.01 µg/g) > *O. mossambicus* (1.18 µg/g) > *L. rosae* (1.18 µg/g)

4.7.6.4 Luvuvhu River

BHC : *O. mossambicus* (0.0010 µg/g) > *L. congoro* (0.0008 µg/g)

Lindane: *O. mossambicus* (0.0400 µg/g) > *L. congoro* (0.0275 µg/g)

DDE : *H. vittatus* (1.37 µg/g) > *L. congoro* (1.28 µg/g) > *C. gariepinus* (0.3300 µg/g)

DDD : *C. gariepinus* (5.84 µg/g) > *H. vittatus* (1.28 µg/g) > *L. congoro* (0.2600 µg/g)

DDT : *H. vittatus* (1.40 µg/g) > *C. gariepinus* (0.168 µg/g) > *O. mossambicus* (0.120 µg/g)

4.7.6.5 *Olifants River*

BHC : *L. congoro* (0.646 µg/g) > *C. gariepinus* (0.0009 µg/g) > *L. rosae* (0.0006 µg/g) Lindane: *O. mossambicus* (0.219 µg/g) > *C. gariepinus* (0.060 µg/g) > *L. congoro* (0.052 µg/g)

Dieldrin: *L. congoro* (0.0044 µg/g) > *C. gariepinus* = *B. marequensis* (0.0010 µg/g)

DDE : *C. gariepinus* (0.460 µg/g) > *O. mossambicus* (0.374 µg/g) > *L. congoro* (0.198 µg/g)

DDD : *C. gariepinus* (0.388 µg/g) > *O. mossambicus* (0.251 µg/g) > *L. congoro* (0.145 µg/g)

DDT : *C. gariepinus* (0.482 µg/g) > *L. congoro* (0.074 µg/g) > *O. mossambicus* (0.011 µg/g)

4.7.6.6 Sabie River

Although the sample size for this river was low the general trend is given below.

BHC : *O. mossambicus* = *H. vittatus* (0.001 μg/g) > *B. marequensis* (0.0009 μg/g)

Lindane: *L. congoro* (0.078 μg/g) > *H. vittatus* (0.031 μg/g) > *B. marequensis* (0.014 μg/g)

DDE : *L. congoro* (0.865 μg/g) > *L. ruddi* (0.540 μg/g) > *H. vittatus* (0.001 μg/g)

DDD : *H. vittatus* (1.58 μg/g) > *L. congoro* (0.935 μg/g) > *L. ruddi* (0.0050 μg/g)

DDT : *L. ruddi* (0.740 μg/g) > *H. vittatus* (0.327 μg/g) > *O. mossambicus* (0.158 μg/g)

4.7.7 Pesticide differences between gender of fish

The following null hypothesis is tested:
The levels of the specified pesticides in males and females within species are not similar.

The null hypothesis is accepted for *C. gariepinus* and *L. congoro* for DDT indication that there is significant differences ($P > 0.05$) between males and females for these samples. The null hypothesis is rejected for all other cases **(Table 39)**.

Table 39: Mann Whitney U test (p) between males and females within species for all pesticides.

Pesticides	Species								
	All	**Om**	**Cc**	**Bm**	**Lm**	**C**	**Tr**	**Lc**	**Lr**
BHC	0.557	0.726	0.732	0.866	1*	0.861	1*	0.643	0.180
Dieldrin	0.096	0.436	0.909	0.735	0.485	0.561	0.637	0.076	0.064
Lindane	0.681	0.591	1*	1*	1*	0.992	1*	1*	1*
DDE	0.149	0.901	0.087	0.668	0.827	0.458	0.141	0.123	0.180
DDD	0.204	0.876	0.909	0.585	0.827	0.357	0.556	0.537	0.443
DDT	0.073	0.342	0.569	0.253	0.694	**0.046**	0.099	**0.045**	0.085
Heptachlor	1*	1*	1*	1*	1*	1*	1*	1*	1*
Endosulfan	0.819	0.809	1*	0.603	0.190	0.488	0.953	0.758	1*
Mercapthion	0.912	1*	1*	1*	0.663	0.864	0.596	1*	1*
Diazinon	0.321	0.773	1*	0.735	0.275	0.080	0.517	1*	1*
Pirimiphos	0.823	0.809	1*	1*	0.827	0.726	0.724	1*	1*
Aldrin	0.936	0.833	1*	1*	1*	1*	1*	1*	1*
Atrazine	0.789	0.846	0.087	1*	1*	1*	1*	1*	1*

1* : No variance

4.8 Expected Pesticides per Catchment

The actual pesticide usage (Agricultural Information Services 1991) in each catchment per crop is indicated in **Appendix E**.

5. DISCUSSION

5.1 Water Quality

In natural aquatic ecosystems, metals occur in low concentrations, normally at the nanogram to microgram per litre level. Recently, however, the occurrence of metal contaminants, especially the heavy metals in excess of natural loads, has become a problem of increasing concern in catchment management. This situation has arisen as a result of the rapid growth in population, increased urbanization, expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices, as well as the lack of environmental regulations.

Results from surveys done to establish potential metals of concern in the catchments studied in this report are shown in **Table 40.**

Table 40: Origins of possible metal contamination to the water quality of each of the catchments (Chunnet *et al.* 1990, SRK 1991, Bath 1992, Claassen 1996, CSIR 1991, DWAF 1995a+b).

Probable Metal Origin	Possible source of metals in each catchment					
	Berg	Crocodile	Letaba	Levuvuhu	Olifants	Sabie
Geological	Fe,Zn, Al, Mn	Fe, Al, Mn, Cr, Zn, As	Sb, Cu, Zn, Fe, Mn	Fe, Cu, Mn, Cr	Fe, Al, Ni, Cr, Cd, Sr, Zn, Pb, Sb, Hg, Cu, Mn, V	Cr, Fe, Mn, Al
Agricultural	Zn, Cu, B	Zn, Cu, B	Zn, Cu, B	Zn	Fe, Al, Zn	Zn, B
Tanning and leather finishing	Cr					
Pulp and paper		Al, B, Cr, Co, Cu, Hg, Pb, Mn, Ni, Zn				
Metal Refineries		Mn, Fe, Al, Mn,B			Fe, Al, Cu, Mn	
Mining*		Fe, Al, As, Zn, Cu, Mn	Cr, Zn, Sb, Fe, Mn	Cu, Fe, Zn	Cu, Sr, Mn, Zn	Fe, Al, As, Mn

* Includes leaching from waste rock and low-grade ore stockpiles, as well as direct mine water and effluent discharge.

The upper reaches of the Sabie River catchment is intensively covered in one of the largest exotic forests in the world. This escarpment is also intensively used for the culture of a wide variety of sub-tropical fruits. The mining activities in the Sabie River have largely ceased which is indicated by the low values of conductivity recorded. The Sabie River is the least regulated of the rivers studied (no impoundments) and consequently shows the smallest deviation from the mean for the water quality constituents analyzed.

The variability of pH in the Olifants River is a result of acid mine drainage originating in the upper catchment from mining activities. The highest impacts of acid mine drainage occurs during low flow situations and can result in high metal concentrations in the rivers.

The Sabie and Crocodile Rivers had the highest dissolved oxygen levels which is related to the constant flow that occurred in these two rivers during the surveys. The lack of impoundments in the Sabie River and the long distance from the major dam in the Crocodile River also added to the higher dissolved oxygen values in these two rivers.

In the Olifants River the relatively high nutrient values are due to nutrients used in the intensive agricultural practices and the mining of phosphate around Phalaborwa. In the Luvuvhu River catchment the nutrients loads originate from agriculture runoff and sewage effluent that is returned to the river in a treated or untreated form.

The high sulphate levels in the lower Olifants River are due to the mining activities in the Phalaborwa area.

The high mean chloride levels in the Olifants River could be the result of industries and mining activities close to sampling points. The Berg River chloride levels could be related to agricultural pesticides, soil runoff and tanning industries.

The relatively higher iron values in the Crocodile River could be due to natural geological sources, exposed geological features from mining and forestry activities and the presence of metal refineries within the catchment (DWAF 1995a). Iron is involved in transport of oxygen in most organisms including fish. It is an essential macro-element that is only toxic at high levels.

The relatively higher levels of nickel in the Luvuvhu River originates from mining activities exposing geological sources.

Zinc values in the Crocodile River could be attributed to industrial, geological and mining sources.

The high aluminium levels in the Klipspruit River, a tributary of the Olifants River, is due to the acid mine drainage (low pH) that emanates from the coal mining activities in this sub-catchment.

The relatively high arsenic values recorded at Kaapmuiden originate in the Kaap River sub-catchment and are due to the large number of closed and active gold mines in this catchment. Arsenic has resulted in fish kills in this catchment in the past 10 years (DWAF 1995a).

The high copper values recorded in the lower Olifants River are as a result of the mining operations around Phalaborwa.

The high manganese values in the Crocodile River upstream of Nelspruit are due to a the leachate of a manganese waste dump (Pappas Quarry). This waste dump originates from a metal refinery in Nelspruit (DWAF 1995a).

If the water quality of the rivers studied is compared with international literature guidelines for protection of aquatic ecosystems (Australian 1992, Kempster *et al.* 1980, Canadian Guidelines 1987, DWAF 1996, **Tables 41** and **42**) the following observations can be made:-

Dissolved oxygen and pH values in all the rivers and at all sites complied to the guidelines for protection of aquatic ecosystems.

Nutrients

None of the rivers complied to the upper range of the guidelines for protection of aquatic ecosystems with respect to ammonia and the Target Water Quality Range (TWQR, DWAF 1996) was exceeded 100 % of the time for all sites studied. Apart from indicating that the rivers studied were enriched by nutrients, due to land usage practises, the TWQR value for ammonia is unrealistic for South African rivers.

Table 41: **Summary guidelines for protection of aquatic ecosystems (Australian 1992, Kempster *et al.* 1980, Canadian Guidelines 1987).**

Indicator	Australian 1992	Kempster *et al.* (1980)	Canada (1987)
pH	6.5 - 9.0	6.5 - 9.0	6.5 - 9.0
Dissolved oxygen (mg/ℓ)	>6	>5	>5
Aluminium (µg/ℓ)	<5.0 (if pH < = 6.5) < 100 (if pH >6.5)	0 - 50	<5.0 (if pH < = 6.5) < 100 (if pH >6.5)
Ammonium - N (µg/ℓ)	20 - 30	16 - 124	
Arsenic (µg/ℓ)	50.0		
Cadmium (µg/ℓ)	0.2 - 2.0	0.1 - 30	0.2 - 1.8
Chromium (µg/ℓ)	10.0	10 - 100	2.0
Copper (µg/ℓ)	2.0 - 5.0	5.0 - 200	2.0 - 6.0
Cyanide (µg/ℓ)	5.0		
Iron (µg/ℓ)	1 000	200 - 1 000	300
Lead (µg/ℓ)	1.0 - 5.0	20 - 100	1.0 - 7.0
Manganese (µg/ℓ)		100 - 1000	
Mercury (µg/ℓ)	0.1	0.5 - 10	0.1
Nickel (µg/ℓ)	15 - 150	25 - 50	25 - 150
Zinc (µg/ℓ)	5.0 - 50.0	30 - 100	30

Metals

Aluminium values in all the rivers exceeded the TWQR of 0.5 µg/ℓ for 100% of the values indicating that the TWQR value for aluminium is unrealistic for South African rivers. The Kempster *et al.* (1980) value of <50 µg/ℓ was also exceeded for 100% of the values in the Berg, Letaba, Sabie and Olifants Rivers. These values are mainly due to background geology and mining activities in these catchments (**Table 39**).

Cadmium

The Kempster *et al.* (1980) value of <30 µg/ℓ for cadmium was complied to for 100% of the values recorded. The TWQR value of <0.07 µg/ℓ is unrealistic for South African rivers and was below the level of detection of the method used to determine cadmium.

Chromium (III)

All the rivers sampled complied to both the Kempster *et al.* (1980) and DWAF values for chromium for the protection of aquatic ecosystems.

Copper

All the rivers complied to the Kempster *et al.* (1980) value of <200 $\mu g/\ell$ for copper. The TWQR value for copper of <0.9 $\mu g/\ell$ is unrealistic for South African rivers.

Iron

With the exception of the Crocodile River (geological and mining origin, **Table 39**) the rivers complied to the Kempster *et al.* (1980) value of <1000 $\mu g/\ell$ for iron.

Lead

All the rivers complied to the Kempster *et al.* (1980) value of <100 $\mu g/\ell$ for lead. The TWQR value for lead of <0.5 $\mu g/\ell$ is unrealistic for South African rivers.

Manganese

With the exception of the Crocodile River (mining, refinery and geology, **Table 39**) the rivers complied to the *et al.* (1980) value of <1000 $\mu g/\ell$ for manganese. The TWQR value for manganese of <180 $\mu g/\ell$ is unrealistic for most South African rivers.

Mercury

All the rivers complied to the Kempster *et al.* (1980) value of <10 $\mu g/\ell$ for mercury. The TWQR value for mercury of <0.04 $\mu g/\ell$ is unrealistic for South African rivers.

Nickel

All the rivers complied to the Kempster *et al.* (1980) value of <50 $\mu g/\ell$ for nickel.

Zinc

The Crocodile, Luvuvhu and Olifants rivers (geological, agricultural and mining, **Table 39**) exceeded the Kempster *et al.* (1980) value of <100 $\mu g/\ell$ for zinc. All the rivers exceeded the TWQR value for zinc of <2 $\mu g/\ell$ which is unrealistic for South African rivers.

5.2 Fish Biology

Only larger species of fish were caught in each river due to the selectivity of the sampling method. The fish species diversity of the lowveld rivers were similar (**Table 11**). The higher number of species in the Crocodile River could be as a result in a higher fishing effort or due to a constant flow during the study. The Berg River's fish catches comprised of exotics (bass and carp) as well as an alien translocated species (Mosambiques tilapia).

Table 42: Aquatic ecosystem guidelines (DWAF 1996)

Constituent	TWQR	CEV	AEV
Aluminium (μg/ℓ)	<0.5	1	10
Ammonia (μg/ℓ)	<7	15	100
Arsenic (μg/ℓ)	<10	20	130
Atrazine (μg/ℓ)	<10	19	100
Cadmium* (μg/ℓ)	<0.07	0.5	6
Chlorine (μg/ℓ)	<0.05	0.1	1
Chromium (VI) (μg/ℓ)	<7	14	200
Chromium (III) (μg/ℓ)	<12	24	340
Copper* (μg/ℓ)	<0.9	0.15	4.6
Cyanide (μg/ℓ)	<1	4	110
Endosulfan (μg/ℓ)	<0.01	0.02	0.2
Fluoride (μg/ℓ)	<50	100	7 000
Iron (μg/ℓ)	10% Of background dissolved iron		
Lead* (μg/ℓ)	0.5	1.0	7
Manganese (μg/ℓ)	<180	370	1 300
Mercury (μg/ℓ)	<0.04	0.08	1.7
pH	not >0.5 pH units of local unimpacted water at time of year		
Phenol (μg/ℓ)	<0.6	60	500
Ortho-phosphate (μg/ℓ)	not >15% of local unimpacted water at time of year		
Selenium (μg/ℓ)	<2	5	30
Temperature °C	>2°C of daily average water temperature		
TDS (μg/ℓ)	<15% of unimpacted water at time of year		
TSS (μg/ℓ)	<10 mg/ℓ of background water level		
Zinc (μg/ℓ)	<2	3.6	36

Where:
* = hardness adjusted for medium water (60-119mg $CaCO_3$/ℓ). TWQR = Target Water Quality, Range. CEV = Chronic Effect value. AEV = Acute Effect Value

None of the species of fish caught in the rivers indicated obvious deformities and all had varying stages of reproduction (GI) which indicated that the populations were recruiting. A more intensive study would be required on each river to determine the population dynamics (recruitment, age and fecundity).

Regressions of standard length against weight (**Table 13**) were only undertaken for *O. mossambicus* and *C. gariepinus* as these were the most ubiquitous and abundant species in the rivers studied. Due to the sampling bias being constant (same stretched mesh size used in all rivers) these regressions of weight to standard length can give an indication of the condition factor of these two species in each river. Table 14's results are indicated below:

O. mossambicus

The following order is for the rivers with the highest regressed weight (g) if a constant standard length of 200 mm is used :

Crocodile > Berg > Sabie > Luvuvhu > Letaba > Olifants

These results indicate that the *O. mossamibicus* in the Crocodile and Berg Rivers at a similar length are heavier than the other rivers. This is due to a combination of factors such as greater predictable river flows, more flood available, less predation, less pollution and generally more favourable growing conditions. The low mass of *O. mossambicus* in the Olifants River could be as a result of the inferior water quality in this river.

C. gariepinus

The following order is for the rivers with the highest regressed weight (g) if a constant standard length of 550 mm is used : -

Letaba > Sabie > Luvuvhu > Crocodile > Olifants

The *C. gariepinus* in the Letaba and Sabie Rivers at a similar length are heavier than the other rivers fish. The low weight in the Olifants River *C. gariepinus* are for the same reasons a for *O. mossambicus*.

The dietary differences between species and rivers indicate different dietary bioaccumulatory paths. Species that are more omnivorous or carnivorous would be expected to have higher metal and pesticide loads than those that are only algae eaters. For the dietary studies undertaken in this report, it would consequently be expected that that the *Labeo* species, Carp, Sharptooth, catfish and Tigerfish would be the best bioaccumulating fish.

5.3 Metals in Fish Tissues

5.3.1 Metal requirements for fish metabolism

Metals are required by fish for metabolism although the levels required are usually in trace amounts. Organs such as the liver plays a detoxifying role in fish.

Levels of **iron** in the **liver** can be ascribed to the ferritin content (Voroby'yev and Zaytsev 1975), iron-containing enzymes and the extensive vascular system of the liver. The haemoglobin in the blood binds approximately three-quarters of the iron present in the body, which explains the high presence of iron in the liver. Elevated iron concentrations in the liver of fish could be due the metal complexing with mucus (Heath 1987). The extensive vascular network in the gills ensures that the blood-borne metals are in contact with the gill tissue (Laurent and Dunel 1980). The high levels of **copper** in the **liver** can be ascribed to the binding of copper to metallothionein (MT), which serves as a detoxification mechanism (Hogstrand and Haux 1991). Copper is also part of the liver proteins hemocuprien and hepacuprien and several oxidative enzymes.

Limited research has been undertaken on the uptake, distribution and excretion of nickel by freshwater fish (Seymore 1994). **Zinc** is primarily taken up in the fish via food (Pentreath 1973, Willis and Sunda 1984). If the levels of zinc in the food are low and/or the zinc levels high in water then zinc can also be taken up through the gills and possible the skin (Skidmore 1964, Handy and Eddy 1990, Hogstrand and Haux 1991). Zinc can also bioaccumulate in the **liver** reflecting the multi-functional role of the liver in detoxification (through metallothionein binding) and storage processes (Carpene *et al.* 1990). **Manganese** can be taken up indirectly with food and ingested sediment via the gut, or directly through concentrations of dissolved metals via the gills (Bendell-Young and Harvey 1986, Hodson *et al.* 1979). This explains the high concentrations in the intestine and gills in this study. **Lead** can be taken up indirectly with food and ingested sediment via the gut, or directly through concentrations of dissolved metals via the gills (Bendell-Young and Harvey 1986, Hodson *et al.* 1979).

5.3.2 Metals in South African fish tissues

In South Africa metal bioaccumulation in fish was first undertaken by Greichus *et al.* (1977 a & b) in the Voelvlei and Hartebeespoort Dams. In recent years there has been a dramatic increase in the fish metal bioaccumulation literature that has been generated in South Africa. Rivers that have been studied include the Olifants (Mpumulanga, Coetzee 1996, Du Preez and Steyn 1992, Grobler *et al.* 1994, Seymore *et al.* 1994b and 1996, Kotze 1997). Crocodile (Roux *et al.* 1994), Sabie. Luvuvhu. Letaba. Berg, Vaal (Adendorff and van Vuren 1996) and Jukskei (IWQS 1994) and dams (Loskop, Middleburg - Barnhoorn 1996, Germiston - Bezuidenhout *et al.* 1990, De Wet *et al.* 1994, Schoonbee *et al.* 1996. Kotze 1997 and Krugerdrift - van den Heever and Fry 1994, 1996 a and b). The rivers and dams with no references indicated were studied in the present study.

A variety of different water bodies ranging from gold mine polluted dams (Bezuidenhout *et al.* 1990 and De Wet *et al.* 1994, Schoonbee *et al.* 1996), sewage effected dams (van der Heever and Fry 1994, 1996 a & b), the middle Vaal (Adendorff and van Vuren 1996), an urban runoff polluted river (IWQS 1994) and various rivers that enters the Kruger National Park (Olifants and Crocodile) after passing through various land usages such as mines and intensive agriculture (Du Preez & Steyn 1992, Seymore 1994, Roux *et al.* 1994, Grobler *et al.* 1994, Coetzee 1996, Claassen 1996, Du Preez *et al.* 1997, Kotze 1997, Robinson and Avenant-Oldewagen 1997).

These above mentioned South African studies have also been undertaken on several species of fish and tissues (**Table 42**). These mean metal values per tissue were converted to a common unit (μg/g dry weight), in order to compare results, using mean tissue moisture contents. The species and rivers were combined. Some 1400 fish have been used in these studies over the past six years. The mean metal value per tissue for these South African studies are indicated in **Table 43.**

This data indicates that the following tissue/organs bioaccumulate the following metals to the largest degree:-

Liver : - copper, iron (all have metabolic roles in liver), cadmium

Gonads : - aluminium, nickel

Intestine : - manganese, chromium

Skin : - lead

Spleen : - nickel

The present lack of a bioaccumulation protocol makes interpretation of these tissue results difficult for the following reasons : -

Intestine : - could be fore-, mid- or hind gut. Intestine will also include food in various degrees of decay. In detrivores the intestine contents will be mainly sediment which could have high metal loads. As the majority of this sediment is released in the faeces the metal values associated with intestine need to be treated with circumspect as there is no clear indication that these metals will stay in the fish (be accumulated) or be excreted as faeces. Also attached to intestine is intestinal fat which can further complicate issues if this is not removed before analysis is undertaken and sediment particles are difficult to remove from the intestine.

Gills : this could be the whole gill, only lamellae, filaments or rakers. Depending on the turbidity of the river the metals found associated with the gills could only be attached to the gill surface and might not be accumulated in the fish tissues. If the gills were thoroughly washed with distilled water before analysis is undertaken for metal then a different metal accumulation pattern could emerge. The extensive vascular network and large surface area of the gills does, however, make them a suitable organ for metal uptake. (Ref).

Skin : this could mean muscle, flesh with or without scales or all of these. If fish muscle is used (as it was used in this study) then it is abundant on the fish and can be used to determine the human health risk if the fish are eaten.

Gonads : this could mean testes or ovaries. Normally associated with these tissues is abdominal fat which would need to be removed before analysis is undertaken. The gonads metal loads are highly variable and are also seasonally dependant. In the non-breeding season the mass of gonads available are limiting for use in biomonitoring studies.

Table 44 indicates the highest metal loads in fish tissues recorded in South African rivers and fish species. For metal bioaccumulation studies using fish in South African river the following tissues are recommended : -

Liver : - zinc, copper, iron, cadmium
Gonads : - aluminium, nickel, - second highest??
Intestine : - manganese, chromium?? second highest
Muscle : - lead

The choice of a specific fish tissue for metal bioaccumulation will be dependant on the specific requirements of the monitoring programme. Different fish bioaccumulation monitoring protocols will be discussed in (**Chapter 6**). Metal bioaccumulation studies using fish in South African rivers could use the following tissues:-

Liver especially for **zinc, copper, iron, cadmium**. Liver is a detoxicanting organ and has high loads of these metals. Most fish livers are easy to dissect as a single organ and are large enough to supply sufficient tissue for metal determination.

Gills especially for **manganese** and **zinc**. Gills are easy to dissect and have direct contact to any pollutants in the water body.

Vertebrae possibly for **strontium** and **zinc**. Could be used to determine long term exposure.

Muscle possibly for **lead**. Should be used to determine the human health risks if this fish tissue is consumed.

Gonads are not considered due to seasonal fluctuations

Table 43 : **The mean metal concentrations per fish tissue (all species of fish and rivers combined,** Adendorff and van Vuren 1996, Barnhoorn 1996, Bezuidenhout *et al.* 1990, Claassen 1996, Coetzee 1996, De Wet *et al.* 1994, Du Preez and Steyn 1992, Du Preez *et al.* 1997, Grobler 1994, Grobler *et al.* 1996, Kotze 1997, IWQS 1994, Robinson and Avenant-Oldewagen 1997, Roux *et al.* 1994, Seymore *et al.* 1994, Schoonbee *et al.* 1996, van den Heeven and Fry 1994, 1996 a and b). **The shaded areas indicate the tissue with the highest metal load.**

Tissue	Mean metal loads (μg/g dry weight)							
	Zn	Cu	Fe	Mn	Al	Ni	Pb	Cr	Cd
Liver	403	179	1434	25	83	36	19	25	9
Fat	40	8	162	5	30	10	16	4	5
Muscle	110	7	156	9	77	31	15	23	6
Gill	663	14	506	76	167	50	21	48	3
Skin	685	26	529	21	52	40	42	39	
Spleen	211	32	1090	8		256	39		
Vertebrae	498	8	243	30		102	29	42	
Intestine	105	29	582	454		58	30	110	7
Gonads	917	10	294	12	259	35	22	32	3
Bile	6	7	60	2		6	8	7	
Brain	335	100							
Heart	196	42							
Kidney	88	17	230	3		4	8	5	

5.3.3 *African and world levels of metals in fish*

Heavy metal concentrations in African and the world freshwater fish muscle are presented in **Tables 45 & 46.** Some differences between waterbodies were observed with respect to the levels of certain elements in finfish. For example, zinc demonstrated relatively higher values in samples from Lake Nakuru, Kenya, followed in decreasing order by those from Zimbabwe and South Africa, Egypt, Nigeria and Ghana. Likewise, copper concentrations were higher in samples from Egypt and Lakes Nakuru and McIlwaine. Although data for iron were scarce, the concentration of this element also seemed higher in samples from Egypt.

The occurrence of trace metals in African Aquatic systems is not excessive when compared to other areas of the world. For example, mean mercury levels in fish were lower by an order of magnitude compared to values reported for mullets in the Tyrrhenian Sea, an area close to naturally occurring mercury deposits (Leonzi *et al.* 1981). They were, however, similar to levels in other tropical, less industrialized areas like Indonesia and Thailand (Gomez *et al.* 1990). The maximum cadmium concentrations were also low compared to fish from British rivers (Mason 1987) and from the coast of the Philippines (Gomez *et al.* 1990), but they were within the same range as levels in other areas (quotes from Biney *et al.* 1994).

5.3.4 *Species of fish that accumulate metals*

The species of fish with the highest metal loads in this study were *L. rosae* (aluminium, copper, chromium, lead), *L. congoro* (cadmium), *O. mossambicus* (arsenic, nickel), *C. carpio* (zinc, manganese) and *H. vittatus* (iron). Carp and tigerfish have limited distributions in the rivers studied and are not easy to catch and consequently are not ideal species of fish for metal bioaccumulation monitoring. Omnivorous or detritivorous species of fish are recommended for metal bioaccumulation studies. The following species could be used in the lowveld rivers of South Africa for bioaccumulation studies of metals:-

L. rosae - occurs in all the lowveld rivers studied, is a **detritivore** that feeds on insects in the sediments.

L. congoro - **algae eater** from rocks

O. mossambicus - **algae eater**

C. carpio -**omnivorous** but grubs in the sediment

These species , with the exception of *C. carpio*,can readily be caught in a seine or gill net and are relatively abundant in the lowveld rivers.

5.3.5 Rivers studied with high metal body loads in fish

The Letaba River fish had considerably higher levels of aluminium, cobalt and iron than the other rivers studied. These high iron levels are due to the local geology and mining activities in the catchment. The copper and lead levels in the fish of the Olifants River were considerably higher than the rest of the rivers. The high copper levels, near Phalaborwa, are as a result of intensive mining, metal refineries and background base geology.

High manganese levels were recorded in the fish from the Luvuvhu River which results from a geological origin.

The rest of the metal levels in the fish from the rivers were not markedly different between the rivers.

Table 44: The highest South African fish species and tissues metal (µg/g dry weight) literature values per river system.

River system and Author	Middle Vaal (Adendorff 1996)	Lower Olifants (Seymore 1994)	Lower Olifants (Du Preez *et al.* 1977)	Lower Olifants (Robinson & Avenant-Oldewagen 1997)	Lower Olifants (Kotze 1997)	Upper Olifants (Coetzee 1996)	Middleberg Dam (Buermann 1996)	Jukskei (DWQS 1994)	This study (mean values)
Copper	Liver, *L. umbratus* 778 µg/g	Liver, *B. marequensis* 80 µg/g	Liver, *C. gariepinus* 20 µg/g	Liver, *O. mossambicus* 144 µg/g	Liver, *O. mossambicus* 177 µg/g	Liver, *L. umbratus* 317 µg/g	Liver, *L. umbratus* 131 µg/g	Liver, *B. polylepis* 72 µg/g	Liver, *L.* [illegible] 1872 µg/g
Iron	Liver, *L. capensis* 1592 µg/g	Hindgut, *B. marequensis* 15 000 µg/g		Liver, *O. mossambicus* 1250 µg/g	Liver, *C. gariepinus* 6328 µg/g	Liver, *L. umbratus* 1579 µg/g	Liver, *L. umbratus* 1513 µg/g	Liver, *C. gariepinus* 1358 µg/g	Liver, *H. vittatus* 3059 µg/g
Manganese	Gill, *L. capensis* 187 µg/g	Gut, *B. marequensis* 1200 µg/g	Gill, *C. gariepinus* 13 µg/g	Gill, *O. mossambicus* 44 µg/g	Gills, *C. gariepinus* 62 µg/g	Gills, *L. umbratus* 79 µg/g	Gills, *L. umbratus* 58 µg/g	Gill, *B. polylepis* 76 µg/g	Gill, *C. carpio* 134 µg/g
Nickel	Skin, *C. gariepinus* 79 µg/g	Gut, *B. marequensis* 45 µg/g	Liver, *C. gariepinus* 22 µg/g		Liver, *O. mossambicus* 52 µg/g	Gills, *C. gariepinus* 34 µg/g	Gills, *L. umbratus* 30 µg/g	Vertebrae, *B. marequensis* 54 µg/g	Testes, *B. marequensis* 4.6 µg/g
Lead	Skin, *L. capensis* 171 µg/g	Gills, *B. marequensis* 32 µg/g	Liver, *C. gariepinus* 48 µg/g		Gills, *O. mossambicus* 26 µg/g	Gills, *C. gariepinus* 21 µg/g	Gills, *L. umbratus* 14 µg/g		Liver, *L. rosae* 454 µg/g
Zinc	Skin, *C. gariepinus* 920 µg/g	Gonads, *B. marequensis* 250 µg/g	Liver, *C. gariepinus* 73 µg/g		Liver, *C. gariepinus* 143 µg/g	Gills, *L. umbratus* 161 µg/g	Liver, *L. umbratus* 136 µg/g	Gonads, *O. mossambicus* 3007 µg/g	Gill, *C. carpio* 382 µg/g
Strontium		Vertebrae, *B. marequensis* 850 µg/g							
Chromium		Gut, *B. marequensis* 150 µg/g	Liver, *C. gariepinus* 45 µg/g	Liver, *O. mossambicus* 84 µg/g	Gills, *O. mossambicus* 63 µg/g	Gills, *C. gariepinus* 58 µg/g	Gills, *L. umbratus* 42 µg/g	Skin, *B. marequensis* 102 µg/g	Fat, *B. marequensis* 8.4 µg/g
Aluminium					Gills, *O. mossambicus* 627 µg/g	Gills, *C. gariepinus* 157 µg/g	Gills, *L. umbratus* 178 µg/g		Gills, *C. gariepinus* 290 µg/g
Arsenic									Liver, *O. mossambicus* 3.1 µg/g
Cadmium									Liver, *O. mossambicus* 0.87 µg/g
Mercury									Liver, *C. carpio* 0.09 µg/g

Table 45: Mean metal concentrations in inland African water fish (μg/g fresh weight, (Biney *et al.* 1994).

Location	Hg	Cd	Pb	As	Cu	Zn	Mn	Fe	References
Lake Mariut, Egypt		0.15			3.7	7.6	0.9	11.2	Saad *et al.* 1981c
Lake Idku, Mariut, Egypt	0.01	0.004	0.67	0.031	1.77	7.4			El Nabawi *et al.* 1987
Lake Nozha, Hydrodrome, Egypt		0.05			3.14	8.0		12.6	Saad 1987
Kpong Headpond, Ghana	0.053	<0.10	0.43		0.36	5.6	0.63		Biney 1991a
River Wiwi, Ghana	0.37	0.19	0.47		0.18	3.0		3.8	Biney & Beeko 1991
Niger Delta, Nigeria	0.034	0.03	0.48		0.70	4.8	1.1	5.4	Kakulu *et al.* 1987b
Lake Nakuru, Kenya	0.044	0.05	0.17	0.36	2.0	22	1.8		Greichus *et al.* 1978a
Lake Victoria, Kenya[a]		0.04-0.12	0.4-1.1		0.15-0.53	2.21-7.02	0.22-0.74	0.53-4.65	Wandiga & Onyari 1787
Lake Mcliwaine, Zimbabwe		0.02	0.17	0.28	1.08	9.6	5.4		Greichus *et al.* 1978b
Hartbeespoort Dam, S. Africa		0.02	0.05	0.26	0.66	11.8	1.6		Greichus *et al.* 1977
Voëlvlei Dam, S. Africa		0.01	<0.02	0.40	0.30	6.6	0.24		Greichus *et al.* 1977
Olifants River, S Africa					30	1000			Seymore *et al.* 1995
WHO Limits	0.05b	2.0	2.0						

[a] Range values

[b] Action level adopted in many countries

Table 46: **Comparison of metal concentrations in fish from Africa and other areas of the world (µg/g fresh weight), (quoted in Biney *et al.* 1994).**

Location	Hg	Cd	Pb	Cu	Zn	References
African inland waters	0.035	0.053	0.31	0.85	7.16	Biney *et al.* 1994
	(0.01-0.053)	(0.004-0.19)	(ND*-0.67)	(0.18-2.0)	(3.0-11.8)	
African coastal waters	0.095	0.069	0.69	0.80	4.76	Biney *et al.* 1994
	(0.06-0.17)	(ND-0.26)	(0.07-1.83)	(0.40-1.65)	(4.23-5.55)	
British rivers	0.17	0.15	0.87			
	(0.023-0.32)	(ND-0.35)	(ND-4.30)		3.92	Leonzi *et al.* 1981
Northern Tyrrhenian Sea	1.21	<0.02	<0.20	0.37	(2.92-5.19)	
	(0.11-2.81)			(0.24-0.44)		Surma-Aho *et al.* 1986
Finnish lakes	0.77					
	(0.50-4.06)					
Northern Indian Ocean	0.01	0.90	0.62	0.81		Sen Gupta *et al.* 1990
Bahrain	0.004-1.07	0.0003-0.071		0.10-0.47		Linden *et al.* 1990
Straits of Malacca	0.01-0.58	ND-0.10	ND-1.20	0.05-0.75	1.70-10.8	Gomez *et al.* 1990
Indonesia	0.02-0.20	0.02-0.03	0.09-0.68	0.33-0.68	0.30-9.96	Gomez *et al.* 1990
Gulf of Thailand	0.01-0.10	0.01-0.06	0.01-0.09	0.50-1.25	6.20-11.8	Gomez *et al.* 1990
Philippines	0.01-1.10	ND-0.36	0.01-0.08	ND-4.43	0.20-58.4	Gomez *et al.* 1990
Hong Kong	ND-0.40	ND	ND-0.30	ND-1.10	0.80-25.4	Gomez *et al.* 1990
New Zealand	0.02-1.10	0.01-0.03	0.03-0.18	0.12-0.75	0.80-5.1	Brodie *et al.* 1990
Papua New Guinea	0.03-0.40	ND-0.10	ND-0.30	0.30-0.70	3.0-5.0	Brodie *et al.* 1990

* ND, not detected

5.4 Pesticides

5.4.1 Pesticides in the aquatic environment

Pesticide residues may accumulate in water, sediment, adjacent vegetation and the biota. Furthermore persistent pesticides are known to accumulate in the food chain resulting in biomagnification between trophic levels (Woodwell *et al.* 1967). The main characteristics of pesticides are presented in **Table 47.** Residue levels are static indices of dynamic processes which, when compared, provide a useful overview of the prevalence of pesticide contamination in the aquatic environment. Data collection identifies the pesticides that are the major contaminants and provides a useful measure of their prevalence, and may indicate the type of organisms that are most likely to accumulate detectable residues.

Table 47: Comparison of the main characteristics of synthetic insecticides (Hellawell 1986).

Characteristics	Organochlorines	Organophosphates	Carbimates
Potential for entry into freshwater	strong	strong	moderate
Solubility in water	very low	low	low
Aquatic toxicity	high	moderate	moderate
Aquatic persistence	prolonged	short	short
Bioaccumulation potential	strong	weak	weak

Although it is possible to detect pesticide residues in the fatty tissues of organisms, the significance of these levels for the organisms have not been established. It is not clear what a certain concentration of a specific pesticide in the fat deposit of an organism means in terms of physiological or biochemical functioning. When animals are stressed or starved, fat is broken down and fat-soluble residues are released into the tissues, thus imposing further stress.

Acute toxicity of pesticides impacts on fish are not discussed in this report as it is the sublethal effects that quietly and dramatically change fish populations in rivers. This sublethal pesticide contamination results from diffuse agricultural runoff.

Sublethal effects of pesticides on fish are vast and vary from changed behaviour, growth inhibition, reduced reproduction to mention only a few. The chronic toxicity and bioconcentration of pesticides in aquatic species of fish significantly decrease growth of the resultant fry, decrease survival and cause histological changes in tissue and delayed mortality in rainbow trout (Mehrle *et al.* 1988). For example, sublethal dosages of endosulfan/deltamethrin sprayed in Botswana to control tsetse fly resulted in a significant reduction of acetylcholenesterase activity and fatty acid concentrations in the liver decreased by 67 % in *T. rendalli*. These sublethal effects can result in overall fish fitness and survival (Merron and Bruton 1992). Sublethal concentrations of endosulfan also resulted in a reduction of nests in spayed areas and fewer juveniles are produced in *O. mossambicus* (Matthiessen and Logon 1984). Sublethal doses of diquat and simazine in rainbow trout leads to elevated frequencies of no-response which results in passive downstream movements which may lead to displacement of trout populations due to delaying of upstream spawning migrations (Dodson and Mayfield 1979).

Pathological changes in gills indicate exposure to pollutants. Severe hyperplasia and hypertrophy of epithelial cells, clubbing and fusion of the secondary lamellae and oedemia in secondary polluted by endosulfan (Nowak 1992). Severe damage in terms of necrosis of gill epithelium results in hypoxia and respiratory failure. These gill effects can reduce the uptake of oxygen from the water which effectively reduces the fish's scope for activity. In addition to this fish encounter problems with ionic and acid base balance.

Uptake of persistent pesticide pollutants such as DDT can vary greatly within species owing to difference in fat deposition strategies. Male pike (*Esox lucius*) contain higher levels of PCB and DDT than females, probably due to the lower elimination via gonadal production. Female germinal tissue can account for as much as 15% of body weight in pike whilst in males germinal tissue only accounts for of body weight (Larsson *et al.* 1993). Organocarbon pesticides are neurotoxins and a change in the rate of oxygen consumption is one of the earliest symptoms of poisoning. Visual assessments indicate an initial increase in respiratory rate (opercular gulping) followed by a fairly rapid decrease prior to death.

DDT was introduced into South Africa in 1945 for malaria control and even though its general use as an agricultural stock remedy has been restricted (van Dyk *et al.* 1982) it is still used in malaria control due to a lack of a suitable replacement. According to Davies and Randall (1989) approximately 121 tons were still being used annually for malaria control in 1985. Latest estimates are that approximately 40 tons were used in 1996 (Bouwman, personal correspondence). It has been suggested that substantial stockpiling for agricultural uses took place especially in the former homelands. Suitable substitutes have already been introduced into Kwazulu-Natal.

The persistent organochlorine pesticides such as DDT are lipophilic compounds that tend to build up in different segments of the aquatic environment. Even though the widespread use of DDT has been banned in many countries residues of DDT and its metabolites are still detected in many aquatic samples collected throughout the world (Wang and Simpson 1996). The biomagnification of hydrophobic organic compounds in fish has been demonstrated in several studies (Russel *et al.* 1995) however the mechanism of biomagnification is not well documented. DDT may establish a concentration in fish 100 000 x's that in water implying a biomagnification factor of 100 000 (Mackay and Clark 1991). Concentrations of DDT pollutants have been shown to be increased in higher-order aquatic predators (Tanabe and Tatsukwa 1984, Wang and Simpson 1996).

DDT degrades to DDE or DDD under aerobic or anaerobic conditions respectively. A dominance of DDT over its metabolites indicates recent contamination of the environment with DDT.

Both organochlorine and organophosphorous insecticides represent majors sources of environmental contamination. The primary acute toxic effects of organophosphates is usually inhibition of acetylchlorine esterase whereas toxicity of most organochlorine pesticides is not based on such a specific mechanism (Arnold *et al.* 1995).

There are numerous reports that chlorinated hydrocarbon pesticides accumulate in various biological systems to much higher levels than those in their surroundings. These discoveries began to cause concern about the possible long-term ecological effects and a wave of public reaction against the persistent chlorinated hydrocarbons started which resulted in stringent restrictions or bans on their use in many countries during the 1970's.

The registrations for the agricultural and domestic use of several pesticides that were determined in the tissues of the fish sampled have been withdrawn in South Africa (Vermeulen *et al.* 1990). A notice to this effect prohibiting the acquisition, disposal, sale and use of pesticides such as DDT, BHC and Dieldrin was published in the Government Gazette of 25 February 1983. **Table 48** indicates the history of these restrictions (van Dyk *et al.* 1982).

Internationally the guideline water quality values for pesticides for the protection of aquatic organisms are varied (South Africa, Kempster *et al.* 1980, Canada 1987, Australia 1992, **Table 49**). These guideline values in rivers and dams in South Africa are difficult to detect due to a lack of a specialised monitoring programme dedicated to the detection of these low levels. In order to be cost effective any pesticide monitoring programme should firstly take into account the actual application rates of the pesticides in the catchment being surveyed. The land usage (forestry or crops), actual pesticides applied to specific land usages, malaria spraying controlling programmes, season, locality and quantity being sprayed should be determined before any attempt to quantify actual values in the rivers systems. Once these facts are determined then areas of highest risk can be sought using parameters such as locality to river system, slope and rainfall. These aspects will further enable a pesticide monitoring programme to be defined in order to minimize costs and maximize the possibility of detecting specific pesticides in the river systems that could be harmful to fish in a sub-lethal manner. Until all these parameters are determined and possibly modelled using tools such as GIS monitoring river systems for pesticides will be a waste of time and money.

Table 48: **Restrictions on the use of certain pesticides in South Africa (van Dyk *et al.* 1982).**

Pesticide	Year of action	Nature of action
Aldrin	1970	Restricted use
	1979	Use limited to soil treatment under buildings
BHC	1970	Agricultural use restricted
	1973	All agricultural uses prohibited
	1974	Withdrawn as a stock remedy
DDT	1970	Agricultural use restricted
	1974	Withdrawn as a stock remedy
	1976	All registration as an agricultural remedy withdrawn
	1976	All sales banned. State use as malaria control only
Dieldrin	1970	Restricted use
	1974	Withdrawn as a stock remedy
	1979	Restricted, State use for moth-proofing, tsetse and harvester termite control
	1984	All sales banned
Endosulfan	1970	Registration on crops for animal feeds withdrawn
Heptachlor	1970	Withdrawn in aerosol and evaporation devices
	1975	Registration withdrawn
gamma-BHC	1970	Withdrawn in aerosols and evaporating devices

5.4.2 *Pesticides in South African fish tissues*

Several studies have been undertaken in South Africa on pesticide residues in fish. These studies range from marine and estuarine (de Kok 1985, Sibbald *et al.* 1986), to inland lakes (Greichus *et al.* 1977) and rivers (Piek *et al.* 1981, Bouwman *et al.*1990, Grobler 1994, Roux *et al.* 1994). **Table 50** indicates the freshwater fish and the mean pesticide residues recorded in the literature. In order to compare these value the literature values were converted to μg/kg on a wet weight basis. Meaningful comparisons of this data are complicated due to the vast variability of methods and tissues used in these studies. For example the tissues used for these determinations were not standardised. The array of tissues varied from whole fish, fish without heads and scales, fillets and muscle and Greichus *et al.* 1977 does not state what tissues were used. To further complicate comparisons are the way that the results are expressed as some are expressed in terms of a basis of fat whilst others are not.

The exact sub-lethal effect that organochlorine pesticides have on fish is still unclear. Residue levels of >2.4 mg/kg of DDT in winter flounder ovaries cause abnormal embryos and comparable residue levels have been found to relate to the death of trout fry in the wild (WHO 1989).

Matthiessen and Logan (1984) reported that low endosulfan levels retard the onset of reproduction in male and female *O. mossambicus*. Endosulfan spraying operations in Botswana cause pathological lesions in brain tissue of *T. rendalli* (Matthiessen and Roberts 1982). Liver damage was recorded in *C. gariepinus* which indicated that endosulfan is excreted in the bile. Further evidence of this was found in *T. rendalli* and *Sarotherodon andersoni* whose bladders were greatly enlarged during the spraying season. The liver was able to cope with the low levels of endosulfan as the *C. gariepinus* livers recovered before spraying ceased (Matthiessen and Roberts 1982). This suggested that the detoxicification mechanisms were stimulated by exposure to endosulfan and there was further evidence as the residues of endosulfan declined in fish tissues before the spraying was completed.

An interesting aspect of change in *C. gariepinus* liver was the accumulation of large amounts of lipid in poisoned tissues (Matthiessen and Roberts 1982). This did not correspond to the seasonal cycle of feeding induced lipid accumulation. This may have been caused by the inhibition of metabolic processes in suboptimally active tissues or that this represents a strategy for coping with sudden influxes of fat-soluble poisons. It has been reported that 'DDT and its stable metabolites are retained in fatty tissues' (WHO 1989). In other studies the fat has also had the highest organochlorine residues (Greichus *et al.* 1977, Piek *et al.* 1981). The muscle levels are lowest (Herzberg 1986, Teron and Sierra 1987).

The current study indicates that the highest mean pesticide loads occur in the following tissues: fat (DDE,DDD, DDT, pirimiphos, atrazine), testes (BHC), liver (dieldrin), gut (lindane, endosulfan, aldrin).

Table 49: Pesticide water quality criteria for the protection of aquatic life. Concentrations are in µg/ℓ (Kempster *et al.* (1980), Australian 1992, Canadian Guidelines 1987).

Pesticide	South Africa (Kempster *et al.* (1980)	Australian	Canadian	United Kingdom
Aldrin	0.01	0.01	0.004	0.01
Chlordane	0.025	0.004	6.0	
DDT	0.0015	0.001	0.001	0.01
DDE		0.014		
Dieldrin	0.005	0.002		0.01
Endosulfan	0.003	0.01		
Endrin	0.002	0.003	0.0023	
Heptachlor	0.005	0.01		
Lindane	0.015	0.003		
Malathion	0.1	0.07		
Methyoxychlor	0.02	0.04		
Parathion	0.008	0.004		
Acephate		20		
Bioresmethrin		60		
Carbaryl		60		
Carbofuran		30		
Chlorfenvinphos		10		
Chlorpyrifos		2		
Diazinon		10		
Dichlorvos		20		
Diclofop-methyl		3		
Methomyl		60		
Permethrin		300		
Propargite		1 000		
Quintozene		6		

Gut as a tissue is not reliable for pesticide residue analysis in fish as the guts with the highest pesticide residue values were found in *L. rosae* in the Letaba River. These "gut" samples were the intestines of the fish which were surrounded by intestinal fat and consequently the high pesticide loads determined are associated with the fatty tissue.

Flesh, skin or muscle: if the actual area where this tissue is collected from the fish and the actual method is specified (dorsal muscle below the start of the dorsal fin, scales removed and skin kept) then this tissue is realistic for pesticide residue analysis as it has an important role in the acceptability of the fish muscle for human consumption.

For pesticide bioaccumulation studies using fish in South African river the following tissues are recommended:-

Intestinal fat:	**DDT, DDD, DDE, Lindane, Endosulfan, Atrazine, Aldrin, Pirimiphos,**
Testes:	**BHC**
Liver:	**Dieldrin**
Muscle:	**suitability of fish for human consumption**

5.4.3 Species of fish that accumulate pesticides

According to the present study there is a high variability of pesticide residues in the species of fish between rivers. The pesticide residues in the species of fish were more determined by the usage of pesticides in the river and consequently the species with the highest concentrations varied considerably between rivers. The following species of fish had the highest pesticide loads in the rivers studied:

Labeo species:	BHC, Lindane, DDE, Heptachlor, Endosulfan
C. gariepinus:	DDD
T. rendalli:	Mercapthion, Diazinon, Pirimiphos
O. mossambicus:	Aldrin
C. carpio:	Atrazine

The review of the limited pesticide studies undertaken on fish in South Africa indicates that due to the lack of standardization of analytical methods (whole fish, decapitated, muscle only etc.) that a wide variety of species of fish have indicated high pesticide residues (**Table 50**). These species vary from algae eaters (*O.mossambicus*), detritivores (*Labeo* sp.), omnivores (*S. intermedius, C. gariepinus*) and piscivorous (*H.vittatus*).

Table 50 : **Literature levels of pesticides recorded in fish in southern Africa** (converted to µg/kg wet weight).

Pesticide	River system					
	Crocodile (Hartebeespoort Dam) Greichus *et al.* 1977 whole fish	**Berg** (Voelvlei Dam) Greichus *et al.* 1977 whole fish	**Limpopo** (Olifants, Letaba, Crocodile) Piek *et al.* 1981 on a basis of fat (muscle, liver, skin) mg/kg	**Pongolo** Bouwman *et al.* 1990 fillets	**Olifants** Grobler *et al.* 1994 head & fins removed	**Crocodile** Roux *et al.* 1994 muscle
DDT	*O. mossambicus* 900 *C. flaviventris* 1200	*M. salmoides* 500 *L. macrochirus* 600	*O. mossambicus* 565 *C. gariepinus* 152 *Labeo sp.* 43	*H. vittatus* 15 sd 17 *O. mossambicus* 7 sd 17 *E. depressirostus* 5 sd 7	*C. gariepinus* (1.7 - 2.2) *O. mossambicus* 2.2 *E. depressirostus* 27.9 (2.9 - 72)	
DDD	*O. mossambicus* 1900 *C. flaviventris* 1300	*M. salmoides* 500 *L. macrochirus* 100		*H. vittatus* 25 sd 33 *O. mossambicus* 17 sd 31 *E. depressirostus* 9 sd 15	*C. gariepinus* (2.5 - 3.7) *O. mossambicus* 1.9 *E. depressirostus* 3.9 (1.0 - 13.2)	
DDE	*O. mossambicus* 900 *C. flaviventris* 1400	*M. salmoides* 4200 *L. macrochirus* 600	*O. mossambicus* 1863 *C. gariepinus* 2880 *Labeo sp.* 379 *Barbus sp.* 918	*H. vittatus* 54 sd 67 *O. mossambicus* 12 sd 17 *E. depressirostus* 13 sd 21	*C. gariepinus* 8.0 (2.5 - 26) *O. mossambicus* 5.6 (3.1 - 8.4) *E. depressirostus* 94 (22 - 198)	*C. gariepinus* 58.5 *O. mossambicus* 14.9 *C. carpio* 3.9 *B. marequensis* 118.9
Endosulfan			*O. mossambicus* 50 *C. gariepinus* 124 *Barbus sp.* 588			
Dieldrin	*O. mossambicus* 1200 *C. flaviventris* 1300	*M. salmoides* 500 *L. macrochirus* 300	*O. mossambicus* 144 *C. gariepinus* 133 *Labeo sp.* 51			
BHC			*O. mossambicus* 37 *C. gariepinus* 38 *Labeo sp.* 19 *Barbus sp.* 26			
Heptachlor						

In South African rivers, due to the limited diversity of carnivores such as *H. vittatus*, who have the best opportunity to biomagnify pesticides in the aquatic environment, omnivores and detritivores should be considered as species of fish for pesticide bioaccumulation studies. Due to the high turbidity of South African rivers, especially after rainfall, the pesticides are most likely to adsorb onto sediment particles and settle into the sediments. **Detritivores would have the best opportunity to accumulate these pesticides from the sediments.**

5.4.4 Rivers studied with high pesticide body loads in fish

The Crocodile River's fish pesticide residue loads indicated that 12 of the 14 pesticides detected were present in the fish tissues. The next highest number of pesticides detected (n = 6) was in the Letaba River. The highly diverse, intensive and all year round agriculture in the Crocodile River accounts for the high number of pesticides detected.

The Letaba River's fish had the highest mean pesticide load, followed by the Crocodile, Olifants, Luvuvhu, Sabie and Berg rivers. The lowveld rivers have a far higher diversity of crops grown all year when compared to the seasonal almost mono-culture in the Berg River catchment.

If the t-DDT values (DDT + DDD + DDE = t-DDT) are compared between rivers fish residues the percentage composition of the t-DDT made up of DDT ranges from 14% (Luvuvhu) to 34% (Letaba). The lowveld rivers still use DDT for malaria control and it is also possible that the high recent usage of DDT in the Letaba River is also due to stockpiling in the former homelands in the catchment. The application of DDT for malaria control is presently being reduced through alternative pesticides even though the malaria incidents is increasing dramatically in the lowveld.

5.4.5 Health risk assessment

As bioaccumulation may produce levels of contamination in commercial species that may be toxic to humans, it is important to monitor key members of food chains such as fish.

The standards established to protect aquatic life in Canada and the United States of America (Water Quality Branch, Environment Canada 1979; National Academy of Science - National Academy of Engineering 1972) recommend that residues in fish muscle (wet weight basis) should not exceed 1.0 mg.kg for t-DDT and 0.5 mg.kg for Dieldrin. If the fish were gutted (i.e. remove fat, liver, testes and ovaries) then the fish would be safe for human consumption (Bouwman *et al.* 1990). This is not always the case as the muscles tissue can be associated with high pesticide loads and the resultant high risk potential as in seen in the present study.

Higher than the recommended risks of 1 in 10^6 were detected for dieldrin, lindane and DDE. Using the maximum level of 120 μg/kg dieldrin detected in fish flesh associated risks as high as 2 in 1000 were calculated based on the assumption of consuming 150g fish 350 days per year (**Appendix F**). For lindane the risk was 3 in 10 000 and for DDE this risk was lower at 3 in 100 000.

Hazard quotients, referring to the non-cancer toxicity were also higher than the recommended US-EPA value of 1 for dieldrin, lindane and endosulfan. Hazard quotients for dieldrin of 2 and 5, calculated for exposure to either 50 g or 150 g fish eaten 350 times per annum, respectively. The hazard quotients for lindane was 2 for exposure to 150 g eaten 350 times per annum. The hazard quotient for endosulfan was 4.2 and 10 for 50 g and 150 g eaten daily and weekly respectively.

The acceptable daily intake (ADI) for humans of t-DDT determined by FAO/WHO is 5 μg.kg body weight (WHO 1989). Assuming a mean body weight of 60 kg and a daily fish consumption of 200 g, the intake calculated on a mean concentration of 36 μg/kg t-DDT for the species of fish in the Letaba and Crocodile Rivers is 0.1 μg.kg.day. The toxicity of DDT levels in the fish of these two rivers is consequently low.

From the results in the present study there are associated human health risks to eating the fish. These risks are however in the worst case scenarios (highest daily weight of fish eaten daily all year round) and are specifically associated with the fish in the Letaba, Luvuvhu and Crocodile Rivers.

5.4.6 Comparison of actual pesticide usage and fish tissues residues

Mean pesticide body loads per species of fish combined were compared to actual pesticide loads used in each catchment. **Table 51** (**Figure 21a** and **Figure 21b**) compares the fish tissues that bioaccumulated pesticides with the actual pesticide usage in the catchments studied.

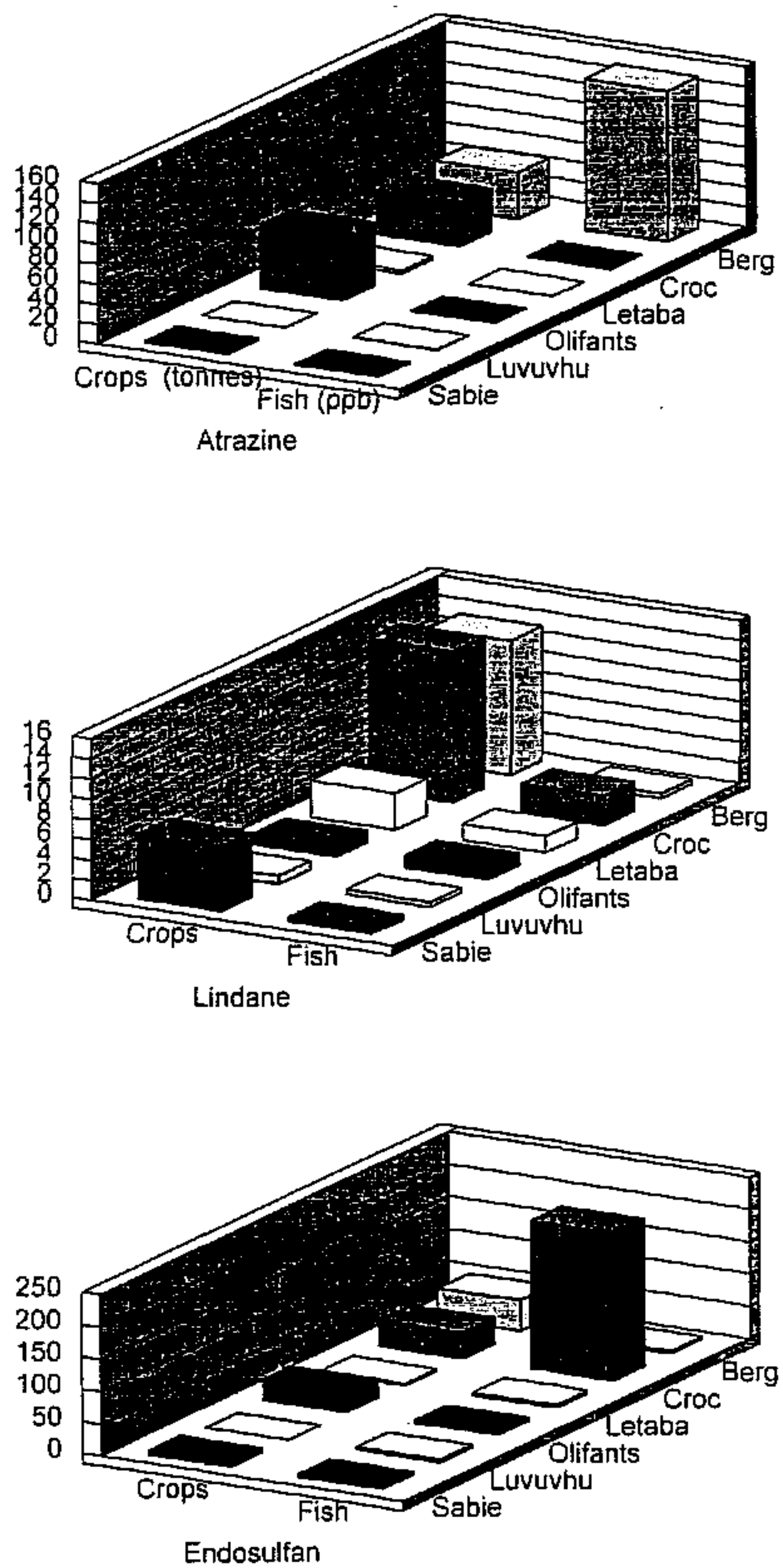


Figure 21a: Pesticide usage and fish tissue residues for Atrazine, Lindane and Endosulfan

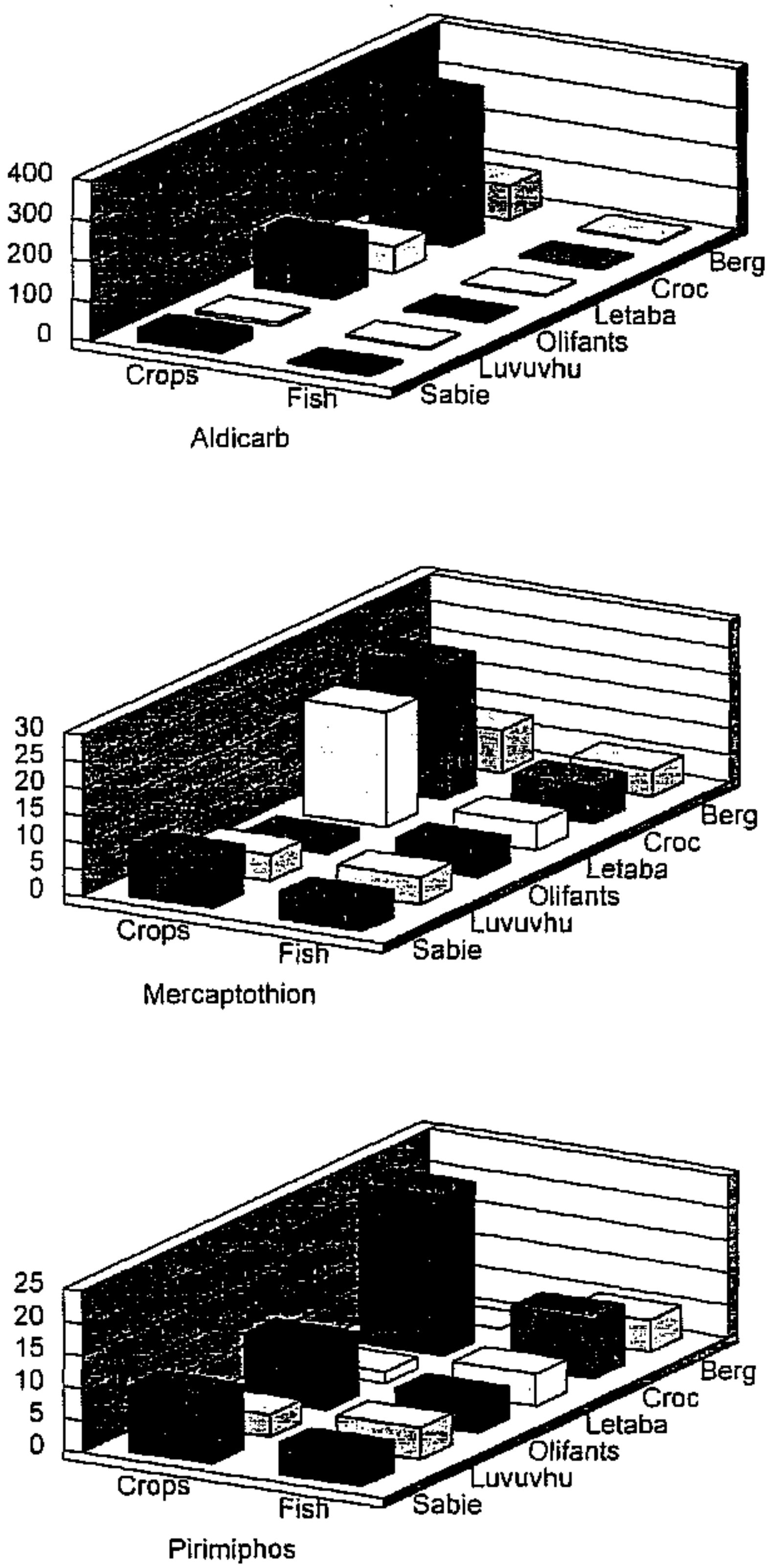


Figure 21b: Pesticide usage and fish tissue residues for Aldicarb, Mercaptothion and Pirimiphos.

Table 51: Comparison of actual pesticide usage for the catchments and the bioaccumulation in the fish tissues.

Pesticides	Berg	Crocodile	Letaba	Luvuvhu	Olifants	Sabie
Lindane	-	+	+	-	-	+
Endosulfan	-	+		?	-	-
Mercapthion	+	+		+	+	+
Pirimosphos	?	+	+	+	+	+
Aldicarb	+	-	+	+	+	+
Atrazine	+	-		-	-	-
DDT etc.						

Where:- - = no bioaccumulation, + = accumulation

Atrazine loads in the fish of the Berg River closely resemble the expected values according to the usage of this pesticide in the catchment (**Figure 21a**). The lack of significant atrazine levels in the tissues of the fish in the other rivers studied indicates that this pesticide is not well accumulated in the tissues or if it is it does not remain in the fish tissues for long periods of time. The relatively high values in the Berg River indicates recent atrazine usage in this catchment.

Lindane residues in the fish from all the rivers studied were similar with the exception of the Letaba and Crocodile Rivers (**Figure 21a**). The Letaba, Luvuvhu and Olifants Rivers indicated biomagnification possible from past rather than present lindane usage in these catchments.

Only the fish pesticide residues in the Crocodile River indicated accumulation that resembled the actual usage of lindane, endosulfan, mercapthion and pirimiphos in the catchment (**Figure 21a** and **Figure 21b**). Mercapthion residues in the Crocodile River were slightly higher than in the other rivers which agrees with the actual pesticide usage in the catchment.

The general trend was that pesticides did bioaccumulate in the fish tissues according to the actual pesticide usage in the catchments (**Figure 21a** and **Figure 21b**).

6. BIOACCUMULATION ASSESSMENT PROTOCOL AND RECOMMENDATIONS FOR FUTURE RESEARCH

6.1 Introduction

Ecosystems provide essential life supporting services to all living organisms, including humans. These services include breathable air, the movement, storage and purification of water, break down of wastes, provision of food, energy, building materials and medicines.

People have been experiencing a sharp decline in the per capita availability of these services, both as a result of exponential population growth and as a result of a sharp deterioration of ecosystems to provide these services. The decline in the capacity of ecosystems to maintain life support services is felt by the poor, who often depend directly on natural resources for their survival.

The realisation that human well being is irrevocably linked to the health of natural ecosystems, means that it has become critical to manage natural resources to ensure their sustainable utilization. It has also meant that the focus of management objectives has shifted, from specific pollutants, to broad objectives related to the maintenance of health of ecosystems.

Environmental monitoring is an integral part of the array of possible monitoring approaches which focus on the evolution and management of water quality. Biosurveys can provide extremely useful information where variable pollutants occur, for monitoring diffuse source impacts, and for monitoring the effectiveness of management practices. However biological monitoring protocols need to be integrated in monitoring programs in order to generate the information that allows effective management of aquatic resources. Biological data must be integrated with physical and chemical data in order to provide meaningful environmental information.

The Department of Water Affairs and Forestry (DWAF) has followed the current world trend, by initiating a series of reports on a National Biomonitoring Programme for Riverine Ecosystems (Hohls 1996) in order to monitor the health of aquatic ecosystems in South Africa. This programme will eventually move towards integrated and cost effective assessment of aquatic ecosystem health. The information generated from a broad spectrum of biological monitoring options will allow an increase in ecological focused management of our waterways. The Department initially surveyed options so that they could develop the necessary infrastructure to conduct routine biological monitoring (including aspects such as bioassessment protocols, acute and chronic bioassays, fish pathology and bioaccumulation testing (Roux 1992).

In South Africa the changes in government has brought with it many changes in approach and legislation and this is also true to the environmental sector. DWAF has published a White Paper outlining its fundamental policy on the environment (DWAF 1994) as part of its approach to managing water supply and sanitation. The key principles are as follows:-

- Protection and conservation of the natural resource base is imperative
- The environment should not be regarded as a "user" of water in competition with other users. but as the base from which the resource is derived and without which no development is sustainable
- The concept of water having economic value should be extended to it also having intrinsic environmental value

It is realised that application of these principles will require the following actions:-

- Developing an understanding of the resource characteristics
- Monitoring of the resource
- Implementating protective measures
- Auditing of development projects

Water monitoring in the form of biomonitoring has a key role to play in providing information to support the above actions (Hohls 1996). Although the above policy of DWAF (1994) on aquatic ecosystems does not view it as an competing water use. protection of aquatic ecosystems must consider the direct and indirect uses of the services derived from it. Therefore, the health of aquatic ecosystems must be maintained at levels that will also protect the uses.

It is assumed that the water bodies reflect the usage of the land that they drain. *Advantages of using bioaccumulation surveys are* : -

(a) biological communities reflect overall ecological integrity (i.e. chemical, physical and biological)

(b) biological communities integrate the effects of different pollutant stressors and thus provide a holistic measure of their aggregate impact. Communities also integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions;

(c) routine monitoring of biological communities can be relatively inexpensive when compared to the cost of assessing toxic pollutants (either chemically or with toxicity tests);

(d) the status of biological communities is of direct interest to the public as a measure of a pollution free environment, while reductions in chemical pollutant loading are not as readily understood by the layman as positive environmental results;

(e) where criteria for specific ambient impacts do not exist, (e.g. non-point source impacts that degrade habitat), biological communities may be the only practical means of evaluation (USA, EPA 1989).

Monitoring of the environment is essential to ensure that the particular water quality management strategy in place is actually achieving the set objectives. Implementation of appropriate manage-ment actions may require the setting of short-term management objectives in order to reach this goal of protecting the health of the ecosystem in a practical and cost-effective manner (Hohls 1996).

Bioaccumulation of aquatic organisms is seen as one of the important aspects that will require monitoring in order to ensure a sustainable ecosystem health. This is linked to the major potential threat to water quality in South African rivers where highly intensive afforestation and agriculture takes place in the upper catchments which are the "power houses of runoff." Furthermore it was recognised at a workshop on ' Preliminary Water Quality Guidelines for the Kruger National Parks rivers' that there is a lack of data on the pesticides and metal pollution levels in South African rivers (Moore *et al.* 1991). Bioaccumulation of metals has also been monitored in South African rivers using crabs, snails and mussels.

The other biomonitoring tools that are linked into the River Health programme are; a macroinvertebrate community index (SASS) which supplies results on river health within an hour in situ, a habitat assessment matix (HAM), a riparian vegetation index (RVI), an fish community idex (IBI) which links with habitat and expected historical fish records, and a geomorphological index. Bioaccumulation studies should not be seen in isolation and should be used as an appropriate tool for determining metal and pesticide pollution on a national scale (comparing baseline data) or on a local impact scale, or for human health risk assessments (see **6.3**)

6.2 Bioaccumulation Objectives

Monitoring will require establishment of scientific protocols to ensure that some national consistency in the sampling methods, physico-chemical and biological indicators, analytical methods and quality control programs are adopted (Australian Guidelines 1992). The objectives of the bioaccumulation programme should be to : -

- directly measure and report the health status and trends of aquatic ecosystems by assessing the 'state of the fish in South African rivers' when comparing the pesticide and metal body loads between rivers and with international literature;
- provide information which can contribute to the assessment of the likely impacts of change in water quality and or flow regime on the health of aquatic ecosystems;
- assess the effects of complex effluents on the health of aquatic ecosystems by specifically assessing the level of pesticide and metal contamination in the major rivers or upstream and downstream of an effluent (using fish as bioaccumulatory indicators);
- provide the baseline information required to serve as basis of broadening the receiving water quality objectives approach to a receiving aquatic ecosystems approach to water quality management; and
- determine the fitness of fish for human consumption through human health risk assessments.

6.3 Methodology Used to Develop a Bioaccumulation System

The following procedure should be closely adhered to in order to develop a functional bioaccumulation system for rivers. This procedure has been adopted from Sanders *et al.* (1987), USA EPA Rapid Bioassessment Protocols for use in streams and Rivers (1989) and the South African experience of biaccumulation using fish. This methodology should be seen as the fundamental rules for the development of a fish based freshwater bioaccumulation protocol.

6.3.1 Systems approach

The whole catchment should be assessed initially in order to determine the processes that drive the water quality in the catchment. Thereafter specific reaches can be selected and specific stations or transects identified within each reach. Historical land usage should also be taken into account as residues could still be in the river system and aquatic organisms.

6.3.2 *Location of sampling sites*

The optimum location of sampling sites is probably the most critical design factor in a monitoring system network. If the samples collected are not representative of the water body, the frequency of sampling as well as the mode of data interpretation and presentation becomes inconsequential.

The water quality of a river reflects natural background conditions and the wastes it is required to carry. As conservative and non-conservative pollutants are added to a river along its length, water quality varies along the entire length. The number of samples required and the sites chosen to collect these samples, are critical.

An approach is to designate sampling sites according to some logical basis e.g. to concentrate sampling near known sources of pollution. While this approach may come closest to generating data which reflects the quality of a river as it varies with longitudinal position, it will nevertheless reflect bias unless a rational systematic procedure for choosing sampling sites is employed.

For many of the regulated rivers in South Africa where dams or weirs cause obstructions to fish and reduce the natural movement patterns of fish sampling, site choice is made simple. Coupled with natural barriers (water falls) many of our rivers are easily segregated into easily defined reaches. Tributaries to the main river are also useful as reaches. Sites (taking accessibility into account) in each of these reaches should be as close to the confluence with other tributaries (or the main river). Furthermore sites should be chosen where the fishing effort will be optimal and the manpower input minimal. If specific point sources of pollution are to be monitored, then barriers to fish movement should be sought above and below the effluent outflow. If no such barrier is available, (no seasonal barrier either) then small cages can be used in which indigenous fish can be kept, above and below the effluent source, for a period of time and the analysis of their body tissue concentrations compared.

6.3.3 *Sampling frequency*

Numerous sampling frequency statistical formulae are available to determine the optimum number of samples needed to sample a river. These techniques are all discussed in Sanders *et al.* (1987). In a South African context the seasonal flows of rivers should be taken into account when determining sampling frequency. The available funds and costs of field data collection and laboratory analysis should also be taken into account to optimize sampling frequency. Available manpower and the cost of the manpower will also determine the sampling frequency. It is important to remember that unimpacted or reference sites should be sought in the same zoogeographical zone to compare with the impacted sites.

6.3.4 *Variable selection*

Inherent in one's choice of what water quality variable to measure is, is some basic understanding of the physical-bio-geochemical processes affecting each variable in the hydrological cycle (Sanders *et al.* 1987). An understanding of what, when and how pollutants are released into the catchment is of primary importance. Certain variables may be greatly diluted by higher streamflows, hence, measurable quantities may occur more frequently during periods of low flow. During these periods the concentrations of pollutants such as pesticides and metals might make up a considerably proportion of the total load in the water bidy. Other variables, such as sediment transport, may be only measured corresponding to higher flows.

Temporal changes in some variables may reflect more on the water users upstream for domestic, industrial, recreational, agricultural or nature conservation purposes. For example some variables may show weekly or seasonal variations which reflect changes in water use patterns.

Knowledge of underlying physical processes and perturbances caused by water use are useful in screening the numerous possible variables for measurement. Specifically for purposes of regulatory monitoring, specific information on industrial processes, irrigation schedules, or seasonal patterns of domestic water use may assist in delineating time, locations and water quality variables of concern.

6.3.5 *Analytical procedures*

Careful collection of samples in the field and possible preservation of samples, if required, is imperative in order to optimize sampling effort. Literature procedures for sample collection and preservation should be followed (Standard Methods 1989).

The analytical procedures should use international standards, accredited laboratories should be used with recognized analyst proficiency. The equipment used will also determine whether or not the sought after levels of detection can be obtained.

During the development of a monitoring programme, a comparison should be made between the analytical results obtained by the industry's analytical laboratory and that used by the regulatory authority. Such an evaluation will reveal whether or not the results obtained by an in-house laboratory will be acceptable to the regulatory authority. Where there are unacceptably large discrepancies between the results from different laboratories, the techniques used should be carefully examined to ensure that they are appropriate for the type of analysis performed. Where necessary, techniques should be adapted to match those preferred by the regulatory authority. It is also important to ensure that the accuracy and precision requirements of the regulatory authority are met.

The laboratories used should also participate in annual accreditation system (CSIR, NLA, SABS or ARC Inter-laboratory Comparison Studies).

6.3.6 Data utilization

The conversion of data into information involves two categories of activities. First, the data must be stored so that it can be properly screened and verified and is easy to retrieve. Secondly, the type of data analysis techniques must be chosen so that the information generated : -

(a) matches the ability of the data to yield such information with confidence, and
(b) matches the needs and expectations of the decision makers (Sanders *et al.* 1987).

6.3.7 Information reporting procedures

Monitoring is undertaken to develop information on water quality conditions. If the data and resulting information are not properly presented and circulated to the information users, the monitoring programme has failed. The reporting format should convey information in such a manner that all users can abstract the information that they require easily and accurately from reports. The reporting format should thus provide the means for meeting the information expectations, in this case the providing of information regarding the status of the fish fauna in the rivers and detection of possible changes over time.

6.3.8 Costs

The underlying factor that will determine the success of a biomonitoring system is the availability and careful use of finances. Sampling frequency, site selection, manpower utilization, variable selection, analytical procedures etc. are all determined by how much money is available. The biomonitoring system should be designed to optimally use these financial resources.

6.4 Proposed Bioaccumulation Monitoring Programme Protocol for Pesticide and Metal Concentrations in South African Rivers.

Good information is the cornerstone for effective management. It is therefore vitally important that in the design and implementation of a water quality monitoring system, the information gathering process is appropriate to the management needs. The monitoring programme must ensure that the right kinds of information are collected, processed, analyzed and presented in a way that allows the success or failure of a particular action or decision to be evaluated objectively. If required, timely decisions can then be taken on the choice of any corrective actions that might be needed.

The existing water quality monitoring programme in the rivers studied does not cover the aquatic ecosystem and consequently the identified shortcoming in this monitoring programme namely bioaccumulation by fish of pesticides and metals needs to be addressed.

This proposed protocol has taken into account the findings of this study as well as numerous interactions with Professors du Preez and Schoonbee's students at Rand Afrikaans University (Barnhoorn 1996, Bezuidenhout *et al.* 1990, Claassen 1996, Coetzee 1996, Seymore 1994, Schoonbee *et al.* 1996, Kotze 1997). The proposed bioaccumulation approach is displayed in **Figure 22.**

The **Table 52** is a synthesis of all the metal fish bioaccumulation data in South Africa that could be accessed. The mean values per tissue are indicated in μg/g dry weight.

Bioaccumulation must be seen as an additional tool in the toolbox of Ecosystem Health determination. This tool will be used to refine problems as one of the River Health indices of the River Health Biomonitoring Programme. The overall approach that should be used when planning for the successful implementation of a fish bioaccumulation assessment as outlined in **Figure 22** .

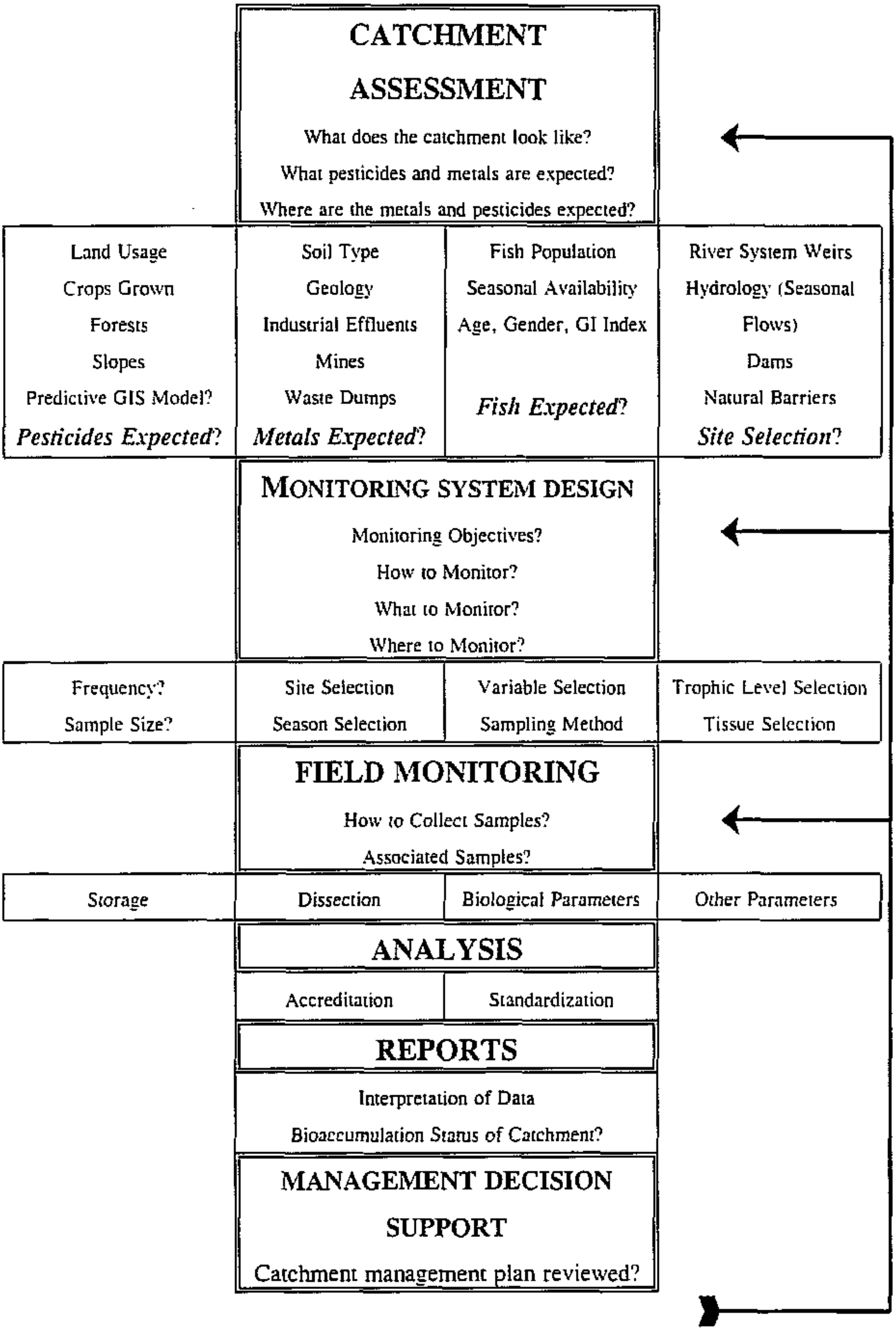


Figure 22 : Proposed bioaccumulation protocol

Table 52 : The mean nett concencentration per tissue for South African literature values

Tissues	Cu	Fe	Mn	Ni	Pb	Zn	St	Cr
	Mean ug/g dry mass							
Fat		161.7	4.73	10.3	15.9	40.2	10.0	3.75
Gill	13.6	506.1	75.5	50.4	20.5	663.1	700.0	48.1
Gonads	9.6	294.0	11.6	34.5	21.7	917.2	26.0	32.3
Intestine*	29.2	582.2	454.6	58.2	30.4	105.0	350.0	110.0
Kidney	16.6	230.0	3.35	4.00	8.00	87.7	9.00	5.00
Liver	179.0	1434.3	25.4	35.7	18.6	402.6	34.0	25.4
Muscle	6.70	156.47	9.40	31.4	14.8	109.9	30.8	23.4
Skin	25.6	528.9	20.6	39.8	42.1	684.8	5.00	38.9
Vertebrae	8.29	242.8	30.3	102.5	28.5	497.9	850.0	42.2
Tissues	**Al**	**As**	**Cd**	**Co**	**Mg**	**Hg**	**Se**	**Ba**
Fat	30.0		4.55	0.66				
Gill	167.0	1.80	3.27	1.80		3.00		
Gonads	259.0	6.50	2.78	2.75	0.88	1.00		
Intestine*			6.83	9.60				
Kidney						4.00		
Liver	82.8	2.50	8.50	5.20	5.00	4.25		
Muscle	76.8	9.00	6.04	0.32		1.50	3.07	23.0
Skin	52.3							
Vertebrae								

The shaded area represents the tissue with the highest metal concentration in all the fish sampled for bioaccumulation in South Africa.

The bioaccumulation protocol can be used for the following aquatic assessments (**Figure 22**): -

- National Rivers Health Assessment of the body loads of pesticides and metals in the fish of the rivers.
- Human Health Risk Assessment if fish used from aquatic resources (resource utilization)
- Impact Assessments or case specific

The protocol should be applied in a hierarchical manner such as:-

National River Health Assessment (level 1)

▼▼▼

Human Health Risk Assessment (level 2)

▼▼

Impact Assessment (level 3)

▼

This bioaccumulation protocol will have close linkages to the following databases or biomonitoring studies : -

- Catchment or situation assessments
- Water quality
- SASS4, HAM, RVI, HQI
- Fish biology, IBI, deformities, parasites, blood haematology, population dynamics, length/mass ratios, liver somatic index, fecundity, recruitment etc.
- WET and ecotoxicology

Sediments as a reserve of metals etc. or as a biotransformer

Bioaccumulation can be used on different scales of impact ranging from rapid (days) or acute, to months (semi-acute), or years, (chronic) populations change.

6.4.1 National River Health Assessment

This national programme should include both bioaccumulation and the IBI at the same sites. This programme will supply baseline data which can be used to compare catchments and be used in management to further determine how well the catchment is being managed.

If a hotspot river reach or catchment is detected through this programme then the next levels of bioaccumulation can be investigated namely Health Risk Assessment or Impact Assessment.

The frequency of this assessment programme is suggested as every 5 years. The sampling season and method as well as the rest of the suggested National River Assessment for fish bioaccumulation is indicated in **Figure 23**.

6.4.2 *Human Health Risk Assessment*

If a fish of x kg's has a body load of y μg/kg what will the human health risk be if a person of z kg eats x grams of fish x days per year? The Human Health Risk Assessment fish bioaccumulation protocol, if implemented, will be able to answer this question.

The major areas where the aquatic resources are used for protein production should be identified and the fish assessed for bioaccumulation of metal and pesticide body loads. This would include subsistence fisheries and recreational fishing and where fish are utilised as a protein source. This is a form of a chronic assessment.

The fish from rivers or impoundments can then be rated according to the Human Health Risk Assessment and recommendations made on the suitability of the fish or mass of fish that would be safe to eat over a period of time. The results of these fish surveys can then published in a pictorial form in a variety of popular publications such as newspapers, fishing journals and entrances of fishing resorts.

Figure 23 indicates the proposed fish bioaccumulation Human Health Risk Assessment protocol.

6.4.3 *Impact Assessment*

In order to determine potential impacts of an effluent (point and diffuse) or a development fish tissue loads can be used by comparing the tissues of a reference upstream site with a down stream site. Fish are mobile which makes this approach difficult unless a natural barrier such as a water fall, or a man made barrier (weir, dam etc.) occur. Cages can also be used by fish being placed in control cages upstream and downstream of a potential impact. The national bioaccumulation protocol results can be used as a comparison or baseline values per species and tissue and compared to the results of this impact assessment.

The following steps should be used for using fish bioaccumulation in impact assessment (**Figure 22**) :-

- understand the catchment and the dynamics that occur
- baseline water quality
- expected impact
- select sites

The frequency will be determine but should be at least seasonal and flow dependant remembering that the highest assimilative capacity occurs at the lowest flow season.

- select species and tissues according to expected impact (see *6.4.5*)
- determine downstream user requirements
- health risks
- whole effluent toxicity
- chemical speciation and bioavailability of pollutant
- link impact assessments with other biolgical monitoring indices such as SASS, IBI.

The use of fish bioaccumulation for an impact assessment study needs to be well planned and the linkages well defined with associated studies (**Figure 23**).

The steps of the proposed bioaccumulation protocol should be undertaken in order to ensure that the correct data is collected at the right rime and at the required level is presented in **Figure 23**.

6.4.4 Catchment or systems approach

The sample sites chosen will depend on a thorough catchment situation analysis of potential and actual point and/or diffuse sources of pollution. In seasonal and/or regulated rivers, dam or weirs, are good places for fish sampling. Sites should be chosen downstream of potential sources of pollution and must be easily accessible year in and year out. A thorough desktop survey with local authorities knowledgeable on the specific rivers should be undertaken before any sampling is undertaken.This step will define upfront what potential sources of pollution are expected in the river being studied and where they are expected.

	National Rivers Health Assessment		Human Health Risk Assessment		Impact Assessment	
Resolution scale	National - catchments		National- subcatchments - reservoirs		Localised - rivers reaches	
Sites	200 National biomonitoring		Recreational and subsistence protein resources		Impact focussed	
Frequency of sampling	5 yearly		3 to 5 years		Needs based (days to seasons)	
Seasons	Either before or after rainy season		Before and after rainy season		Needs based (days to seasons)	
Purpose	Baseline of status of fish body loads		Human health risk assessment of eating fish		Determine potential impacts of effluents	
	Pesticides	**Metals**	**Pesticides**	**Metals**	**Pesticides**	**Metals**
Fish trophic level	*Omnivore*	*Detritivore - Omnivore*	*Eaten or utilised species*		*Most abundant indicator of specific pollution*	
Tissues	Fat - gonads	Vertebrae - flesh	Flesh - fat	Flesh	Fat - gonads	Liver - gills
No. of samples	5	5	5	5	> 10	> 10
Sampling method	Gill or seine nets or shocker				Seine or gill nets, or cages	
Variable selection	Organochlorines, triazines	Fe, Mn, Zn, Co, Cu, Al, Mg	Organochlorines, triazines	Hg, As, Cu, Pg, Cr	Impact dependant	
Linkages	National Rivers Health Programme Cathment Situation Assessments		Human Health Risk Assessment databases Deptment of Health		Waste load allocation Impact Assessment Risk Assessment Chemical Speciation Catchment management Whole Effluent Toxicity Biomarkers	

Figure 23 : Proposed levels of assessment for which fish bioaccumulation can be used.

6.4.5 Monitoring system design

6.4.5.1 Choose sample sites

The sampling sites will be determined largely by the river system in each catchment (weirs, waterfalls, accessibility etc.). Further refinement of the sites will also be determined by the level of monitoring to be undertaken and the exact level of bioaccumulation assessment that is to be undertaken : -

Level 1 : (National River Health Assessment) will for example use a broader scale with respect to the number of sample sites and samples taken. The sites chosen will probably only be at the end of a specific order of a river (i.e. before the confluence of two major rivers). The frequency of sampling would also be longer at around 5 years (**Figure 23**).

Level 2 : (Human Health Risk Assessment) would have a more specific monitoring system design dependant on needs defined by a preliminary or scaping assessment. If a specific body of water is being used for protein supplementation (via angling) then the human health risks need to be determined. If a human health risk is predicted then the monitoring programme design will need to be customised to effectively determine the severity of the human health risk.

Level 3 : (Impact Assessment) monitoring programme design would have the most intense monitoring programme. The resolution and frequency of sampling etc. could be from days to months (**Figure 23**).

6.4.5.2 Number of samples to be taken

There is a high variability in tissue loads within the same species at the same site. This variability should be taken into account when planning the bioaccumulation monitoring programme. This aspect needs to be thoroughly discussed with a statistician before the sampling commences as part of experimental design. The specific requirements of the monitoring programme must also take into account the catchability of the fish, the large size of tissues required for analysis and the high costs of analysis. It is important to note that due to the above mentioned constraints the ability to ideally collect enough samples is difficult. Furthermore the abundance and availability of fish in some rivers in South Africa is low making the collection of fish difficult. Care must also be taken in not over exploiting fragile fish populations through over zealous destructive capture techniques and too frequent monitoring programmes.

A general approach with respect to the number of samples to be taken per level is given in **Figure 23**

Variable selection

The choice of variables to be monitored will vary from catchment to catchment and from site to site, depending on agricultural land usage, industrial effluent, soil and geology, and other land uses. Certain pesticides do not accumulate in biological tissues, and although they may be toxic at high concentrations, they are not be detected in fish tissues. Other pesticides have a very short half-life and would also not accumulate in fish tissue.

It is important understand the river system being studied and consequently come to terms with what is expected to be in the rivers before and field work is undertaken. Actual pesticide usage databases will assist variable selection as well as interviews with extension offices of the Department of Agriculture. Metal load estimates from industrial and mining effluents can be determined with assistance form the regional DWAF office. Literature reviews of pesticide and metal accumulatory capabilities needs to be done before variables are selected.

Figure 23 suggests the most common methods and pesticides that could be monitored per level of assessment.

Frequency of sampling

It is suggested that for pesticides and metals that the bioaccumulation studies of fish in South African Rivers takes place every five years. This National River Health assesssment could be phased in with initial emphasis being on priority rivers as determined by DWAF and conservation organizations. This National River Health Assessment bioaccumulation monitoring programme should include other forms of biological monitoring such as bioassessments (IBI and SASS3), habitat assessments and toxicity studies (Heath 1993). These associated biological assessments would be undertaken as part of the River Health Programme of DWAF, and would further include RVI and HQI.

This proposed five-yearly monitoring programme is contrary to the bi-annual surveys suggested by Moore *et al.* (1991) and Van Wyk (1992). The logistics (trained manpower and costs) preclude more than an annual bioaccumulation survey of South African rivers. The highly variable rivers flows and the low abundance of fish in these rivers further preclude more frequent sampling.

Level 2 sampling frequency would be determined by the health risk severity and the relative importance of the river as a protein source.

Level 3 sampling frequency would be dependant on the specific objectives of the study as well as the site (river or dam). Initially the frequency should be at least quarterly or until the impact has been determined, the frequency can be refined.

The timing of sampling of these levels will be dependant on the flow regime in the rivers. During the breeding season (summer) certain species of fish migrate making catching difficult as well as the fish absorbing their abdominal fat and using this reserve for breeding purposes. The best season for maximum concentrations of fat in fish would be pre-breeding when the fish accumulate extra fat reserves for breeding.

Other sample to be taken during the bioaccumulation surveys

Physical water measurements
Chemical water quality (metals, nutrients)
Sediments (upper 5 cm, metals and pesticides)
Biological data - age, mass, standard length, stomach contents,
Fish Health Assessment Index, fish conditions, parasite loads, lesions etc.
Fat and moisture content of the fish tissues

Specific tissues

The size of the fish caught will determine the amount of tissue available for analysis. For pesticide analysis *ca* 20 g (wet weight) of tissue are necessary. Future techniques indicate that <5g will be sufficient. For metal analysis *ca.* 1 g (wet weight) of tissue is necessary. More sophisticated analysis techniques and equipment are available overseas that enables smaller quantities of tissue to be used for analysis. At present these techniques and equipment are not available in South Africa.
The specific tissues to be taken will depend on the purpose of the study (**Figure 23**. for example:-

Metals

Level 1 : (National River Health Assessment): These studies will include tissues that are sensitive to bioaccumulation and will effect the physiological processes in the fish. Suggested tissues are liver, gills and gonads. For long term studies (trends): liver (iron, copper, cadmium), vertebrae (nickel), intestine (chromium, manganese), gonads (zinc, aluminium), skin (lead).

Level 2 : (Health Risk Assessment): It is assumed that the people that eat these fish will gut the fish. The suggested tissues are muscle and skin.

Level 3 : (Impacts Assessments): this would require tissues that have a rapid accumulative response time. Gills and liver are suggested for metals.

Pesticides

For the pesticides residues detected in this study the following tissues are suggested.

Level 1 (trends): gonads : (BHC, DDT, DDE, DDD, Dieldrin) and fat (BHC, DDT, DDE, DDD, Dieldrin).

Level 2 Health (Risk Assessment): It is assumed that the people that eat these fish will gut the fish. The suggested tissues are flesh and fat (associated with fatty muscle).

Level 3 : this would require tissues that have a rapid accumulative response time. Gonads - testes (pre-breeding season) and liver are suggested.

Trophic levels of fish used for bioaccumulation studies.

Due to the patchy distribution of fish species in South Africa it is of benefit to select specific trophic levels of fish rather than species.

Metals

Level 1 : It is proposed that for metals detritivorous or omnivorous species of fish be collected.

Level 2 : Utilized or most eaten species.

Level 3 : Most abundant indicator of specific pollution.

Pesticides

Level 1 : It is proposed that piscivores or omnivores are collected for persistent residues. Care must be taken in selecting species of fish in rivers that are regulated as the piscivorous fish could be under pressure due to restricted migrations. The more modern biodegradable pesticides which do not bio-magnify would possible be found in detritivores that accumulated particles with adsorbed pesticides.
Level 2 : Utilized or most eaten species.
Level 3 : Most abundant indicator of specific pollution.

Timing of sampling

Level 1 + 2 : Due to seasonal rainfall and floods, it is suggested that fish are collected between April and September (for the summer rainfall areas) and November to March (for the winter rainfall areas). This enhances the catch per unit effort, reducing sampling time and manpower.
Level 3 : The timing of the survey will be needs based.

Sampling method

The fishing methodology will depend on the river geomorphology, flow, river width, manpower and equipment. Seine nets would be preferable as only the fish needed can be sampled and the rest returned unharmed. Gill nets can also be used if the river is flowing too fast, its bottom too rocky, too much debris on the bottom or sides or if the river is too deep. For impact assessment cages could be used with fish being placed upstream and downstream of the potential impact.

6.4.6 Field monitoring

Dissection and storage of tissues.

Tissue terminology should be standardised for example muscle (muscle tissue without the skin and scales and deboned as far as possible etc.).

Tissues should be dissected in a clean environment and using clean dissection equipment in order to prevent contamination.

The samples should be stored in clean, clearly labelled glass or plastic containers in a freezer at -5 °C . The samples should not be kept in storage for long periods before analysis is undertaken.

6.4.7 Analysis of samples

Analytical methods

Need to standardise on methods and the method used should be clearly reported in the results.

Quality control

Analysis should be undertaken at accredited analytical facilities using internationally accepted methods.

6.4.8 Reporting of results

Data storage

The data base generated by this proposed national bioaccumulation programme must be:-

- coordinated by DWAF (even though the provinces will undertake the assessments)
- custodian
- data bases intended - open - seamless
- housed at a central and accessible institution
- updated regularly
- data must be free of charge
- the internet provides an ideal infrastructure for such a shared data base

DWAF needs to be custodian of the data derived from biological monitoring and this data should feed into a decision support system in which this biological monitoring data can be compared to and combined with water quality data, habitat assessment data, etc. so that managers can make decisions on a wide range of data. The bioaccumulation assessment data should be based on the same national database as proposed in the River Health Programme.

Reporting

The bioaccumulation monitoring programme must be designed as a management information system and used as a DSS. It must fit in with the Rivers Health Programme for Riverine Ecosystems of DWAF.

The results must be made public information in an easy to understand format. Indices need to be developed in order to convey the status of the fish, the river health etc. so that the whole populous of South African can understand what the results mean and what they can possibly do to improve the water quality and aquatic ecosystem status of our rivers.

6.4.9 Management decision support

Management interventions

A bioaccumulation protocol needs to be in line with the River Health Programme goals. If management targets are set then the results of the bioaccumulation monitoring programme must be used to determine the success of the catchment management plan and suitable management interventions undertaken until such time as the targets are reached.

The results of the bioaccumulation assessment can be used to audit how effective the catchment management interventions have been over a period of time, in effect used every five years to re-assess the situation assessment.

7. RECOMMENDATION

Biological monitoring in South Africa will improve the current water quality management programme. The aquatic ecosystem can be used to verify the effectiveness and validity of the currently used water quality management programme.

7.1 Biological Monitoring Development Needs

Biological monitoring development in South Africa has in the past been fragmented with minimal collaboration between researchers. The different biological monitoring disciplines are not all on the same level of development and have not all got the same common vision for the "better management of South African water quality". The National Biomonitoring Programme for Riverine Ecosystems will seek to address this issue.

There is a large amount of development, verification and implementation required before biological monitoring in South Africa can take its rightful role in assisting water quality management. This development needs to be facilitated and controlled so that the aims and objectives of DWAF's policies and mission statement with regards to the aquatic ecosystem are met. With the limited time and money available this development needs to be well co-ordinated (Heath 1993). The National Biomonitoring Programme for Riverine Ecosystems will focus initially on SASS4, IBI and HAM. Financial and training support should be given to this programme throughout South Africa.

7.2 Linkage of Bioaccumulation Studies with Human Health Risk Assessment

International data bases on human health risk assessment must be accessed to determine the risks associated with the human consumption of fish tissues contaminated with pesticide and metals. This is an important issue not only for freshwater fish but for estuarine and coastal fish that are a staple protein source for a large proportion of our population.

7.3 Ongoing Refinement

Liaison with DWAF and NCC on their on-going development of the National Biomonitoring Programme for Riverine Ecosystems is imperative in order to develop a more holistic, integrated water quality management strategy for South African Rivers (including chemical, physical and ecological monitoring programmes). The bioaccumulation protocol needs to be re-assessed and refined after initial application in rivers. The tissues selected for specific bioaccumulation studies as well as the trophic levels selected for need to be verified in a variety of riverine ecosystems.

7.4 Standardization of Techniques

The analytical techniques used to determine pesticides and metals need to be standardized for comparative purposes. These standard techniques should include sampling procedures, tissues and species used for bioaccumulatory studies. The data reported should also be in standardized units for example μg/g or mg/kg dry weight. This standardization will reduce possible errors in converting from other units.

In order to effectively determine the bioaccumulation of lipophilic pesticides the actual percentage lipid composition in tissues should be adjusted so that the results are expressed or normalised to lipid content.

7.5 DWAF Custodian of Results

The data collected on fish and other organisms in terms of bioaccumulation studies should be stored at central institution whose responsibility it should be to update and do quality control on the data collected. DWAF is ideally suited for such a role as they already collected the National, Regional and Compliance monitoring water quality data which should be linked to bioaccumulatory data. DWAF (IWQS) and CSIR are currently working on a GIS based nation wide, updateable, statistical management product that will enable user friendly outputs to be generated in the form of colour coverage. This format is ideally suited for "State of Nation" reports.

7.6 All Bioaccumulatory Studies Synthesized

The synthesis of all the varied bioaccumulatory studies is imperative. As different organisms and rivers have been studied by different organizations it is now timeous to integrate and interpreted all these studies in order to not have any duplication of studies, and to decide on what organism, tissue, species, method that should be used in a state of nation assessment. This report has synthesized the available data in reports but the task would have been easier had a national database and custodian been in place. The state of our rivers in terms of the body loads of fish and the corresponding suitability for human consumption could be published once at least every five years. In areas where inland waters are extensively used for recreational and subsistence angling the frequency of determining the health status of the fish should be at least seasonal.

7.7 Research Needs

- Controlled laboratory studies to determine the pesticide and metals uptake rates and response times in fish tissues in typically high turbidity water.

- Correlate pesticide and metal sediment loads with fish tissue loads. High turbidity rivers in South Africa could result in the majority of the pesticides and metals loads settling into the sediments rather than been transported in the river for long distances.

- Tissue selection needs further refinement especially gills, intestine etc.

- Sublethal behavioural changes in breeding success, breeding migrations should be monitored in rivers with high pesticide and metal loads. This would require a combination of laboratory experiments and fish population dynamics and behaviour studies in non-turbidity rivers.

- Fish population dynamics (fecundity, mortality etc.) should be compared with bioaccumulated body loads of pesticides and metals.

- Bioaccumulation fish body loads need to be compared with fish health indices.

- Bioaccumulation must be linked in a cost effective manner with IBI and fish health index.

- Areas of aquatic ecosystems (freshwater, estuaries and coastal zone) with high bioaccumulation rates need to be identified nationally and the local subsistence populous informed and educated about possible health risk. Standard practises such as gutting all fish and throwing away fatty tissues should be instilled in these populations.

- Analytical techniques need to be refined in order to allow smaller tissues samples to be analyzed especially for pesticide residues. New generation pesticides should also be able to be detected. These methods must be standardised and interlaboratory studies undertaken to compare results.

- Natural background origins of metals in rivers needs to be quantified according to the local soil types, geology and land disturbances so that these background levels

- User friendly, easily understandable icons or cartoons need to be developed as an educational tool for grass roots training at primary schools. Bioaccumulation indices need to be developed for the general public so as the current status of our rivers can be easily understood.

Biological monitoring in South Africa will improve the current water quality management programme. The aquatic ecosystem can be used to verify the effectiveness and validity of the currently used water quality management programme.

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Appendix A
Water Quality Data

RIV	DATE	STATION	oC	COND	pH	DO	NTU	ORT-P	KJEL-N	NH4-N	NO_2+NO_3	NO3-N	TOT-P	Na	K	Ca	Mg	SO_4	Cl	TDS	TSS	Alk	B	F	Al	As	Co	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn	Hg
				m S/cm				µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	g/l	µg/l
BER	27-Oct-93	misverst	23.6	80	7.2	5.7	0.7	10		100	100		100	7		3			20	76	13			400	164		12.5			12.5	60	25	12.5	12.5	12.5	
BER	26-Oct-93	voelvlei	21.5	140	7.2	5.8	7.3	100		300	600		300	20		4			47	157	55			100	345		12.5			12.5	370	25	30	12.5	12.5	
BER	05-Oct-93	misverst	23.3	500	7.7	10.8	0.1	100		400	700	50	200	71		12			120	315	12.5			300	195						120		50			
BER	05-Oct-93	voelvlei	16.5	80	8.1	10.8	0.1	100		100	200	50	200	11		3			18	52	12.5			500	311						90		12.5			
CRO	15-Jun-89	matalfin		142	8.1			22	75	49	194		58					4	5	73.3			159	272			12.5	2.5	12.5	12.5	528	25	44	12.5	12.5	0.5
CRO	14-Jun-89	hengel		156	8.1			18	354	338	280		61					5	6	74.7			137	162			12.5	2.5	12.5	12.5	567	25	439	12.5	12.5	2
CRO	14-Jun-89	tenbosch		290	8.3			46	75	97	758		104					5	13	164			133	324			12.5	2.5	12.5	12.5	467	25	111	12.5	139	1
CRO	13-Jun-89	rivside		255	8.2			59	75	136	712		62					5	11	132			97	287			12.5	2.5	12.5	12.5	456	25	117	12.5	29	0.5
CRO	14-Jun-89	kaapmuiden		182	8.2			58	75	58	646		104					5	6	94.7			165	250			12.5	2.5	12.5	12.5	356	25	66	12.5	256	0.5
CRO	15-Jun-89	montrose	12	139	8.2			13	75	56	114		63					6	5	70.7			141	250			12.5	2.5	12.5	12.5	500	25	28	12.5	86	1
CRO	12-Sep-89	tenbosch	18.7	422	7.8	6.7		100	100	100	700	50	100					23	15	218.6			183	298							178	25	62		249	0.5
CRO	12-Sep-89	rivside	19.6	321	7.7	9.3		100	200	100	2000	50	100					25	17	148			169	320							222	25	59		313	0.5
CRO	14-Sep-89	croc_hot	17.9	146	5.8	10.6		100	100	100	400	50	100					7	7	54.6			171	275							444	25	31		380	3
CRO	14-Sep-89	matalfin	18.3	158	8	14.4		100	200	100	400	50	100					7	5	43.9			100	365							400	25	31		94	0.5
CRO	12-Sep-89	kaapmuiden	19.7	196	7.6	11.5		100	200	100	1900	50	100					9	7	78.6			114	343							222	25	82		49	0.5
CRO	13-Sep-89	hengel	16.5	179	7.8	9.6		100	1000	900	1000	50	100					19	5	58.6			176	348							400	25	878		12.5	0.5
CRO	13-Sep-89	montrose	17.6	136	7.5	10.5		100	100	100	400	50	100					8	5	55.9			145	326							600	25	44		730	0.5
CRO	09-Jan-90	kaapmuiden	24.8	150	8.2	8.7	5	108	75	40	705		108					25	7	84			86	282							261	25	46		84	0.5
CRO	11-Jan-90	croc_hot	21.9	100	8	9.4	15	24	75	77	86		118					9	5	61.3			171	462							1189	25	12.5		111	0.5
CRO	11-Jan-90	montrose	21.7	100	8	8.6	18	30	75	104	64		94					7	5	53.3			241	147							700	25	12.5		122	0.5
CRO	11-Jan-90	matalfin	22.5	120	8.2	7.6	8	28	75	123	194		90					13	6	60			76	210							1078	25	12.5		100	0.5
CRO	09-Jan-90	rivside	26.2	240	8.2	.8	4	47	152	67	574		99					17	15	134.6			110	273							189	25	12.5		87	0.5
CRO	11-Jan-90	lions	22.5	120	8.2	8.2	6	28	75	78	196		94					11	5	64			208	223							600	25	12.5		83	0.5
CRO	09-Jan-90	tenbosch	24.2	280	8	7.9	2	44	75	43	522		77					22	14	157.3			137	256							78	25	12.5		71	0.5
CRO	10-Jan-90	hengel	22.3	130	8.1	8.1	4	31	258	200	413		88					17	6	66.6			108	244							300	25	32		72	0.5
CRO	07-Mar-90	lions	22.5	98	8	8.5	10	8	75	25	183		147					4	6	85.3			97	307							978	25	80		717	0.5
CRO	09-Mar-90	matalfin	21.7	90	8	8	300	196	291	285	289		211					22	12	182.6			538	340							2867	25	328		1028	0.5
CRO	08-Mar-90	croc_hot	22.2	103	8.2	9.8	6	8	156	18	155		62					7	5	55.9			52	240							533	25	50		550	0.5
CRO	06-Mar-90	rivside	25.1	143	7.9	7.8	17	34	75	36	568		65					9	9	115.9			56	300							1222	25	222		933	0.5
CRO	06-Mar-90	tenbosch		166	7.8		16	45	186	35	499		92					10	10	99.9			71	380							878	25	133		350	0.5
CRO	07-Mar-90	hengel	23.3	91	8.1	7	9	13	216	154	361		71					7	6	78.6			77	173							900	25	494			0.5
CRO	08-Mar-90	montrose	22.5	100	8	9.8	4	8	75	22	60		66					7	6	63.9			56	267							556	25	41		200	0.5
CRO	06-Mar-90	kaapmuiden	24.6	110	8	9.7	15	39	75	30	1512		71					8	7	95.9				180							1178	25	328		5560	0.5
CRO	08-Mar-90	rivuletts	22.5	97	8.1	9.2	7	14	158	28	153		68					5	6	77.3			52	320							578	25	50		33	0.5
CRO	13-Jun-90	hengel	12.9	240	8.5	12	2	14	401	391	305	8	72					11	5				78	133							440	25	384		1780	0.5
CRO	13-Jun-90	lions	13.5	260	8.4	12.6	3	27	75	84	164	7	70					8	6				72	125							430	25	46		135	1
CRO	12-Jun-90	kaapmuiden	16.1	380	8.1	12.7	0.1	51	75	53	790	8	86					11	8				99	125							220	25	12.5		487	0.5
CRO	12-Jun-90	tenbosch	16.9	720	7.8	10.5	1	19	75	44	450	11	65					13	20				66	142							220	25	68		1300	3
CRO	14-Jun-90	montrose	13	200	8.6	12.9	3	11	75	23	90	6	59					6	5				105	163							425	25	12.5		1460	0.5
CRO	14-Jun-90	matalfin	12.6	250	8.7	11.4	35	17	207	205	203	7	64					10	7				129	121							440	25	212		1420	1
CRO	14-Jun-90	rivuletts	13.9	150	8.3	12.6	3	17	75	87	131	7	109					7	6				102	150							495	25	12.5		125	1
CRO	14-Jun-90	croc_hot	13	230	8.5	10.1	4	21	75	35	162	6	74					9	5				120	158							480	25	12.5		1640	2
CRO	12-Jun-90	rivside	18.1	770	7.7	12.1	0.1	10	156	31	418	16	65					13	14				54	133							175	25	42		166	6
CRO	11-Oct-90	montrose	21.2	250	7.3	9.5	4	100	300	200	200		600					17	4	88			1000								570	25	28		1125	1
CRO	11-Oct-90	croc_hot	21.6	280	7.3	8.3	3.5	100	300	200	300		500					17	6	113			911								690	25	50		2625	0.5

RIV	DATE	STATION	oC	COND	pH	DO	NTU	ORT P	KJEL-N	NH4-N	NO_3+NO	NO3-N	TOT P
				m S/cm				µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
CRO	10-Oct-90	lions	20.2	220	7.4	10.9	6.5	100	100	300	300		500
CRO	10-Oct-90	hengel	20.5	280	7.5	9.1	7.5	100	300	300	400		500
CRO	11-Oct-90	mataffin	20.6	260	7.4	11.6	4	100	500	400	300		500
CRO	09-Oct-90	rivside	23.3	440	7.2	7.2	4.5	100	300	300	400		400
CRO	09-Oct-90	tenbosch	22	460	7.8	6.2	1.5	100	300	300	100		400
CRO	09-Oct-90	kaapmuiden	22.2	270	7.4	11.9	6	100	300	400	900		500
CRO	12-Oct-90	rivuletts	21	180	7.4	7.6	5	100	200	200	200		500
CRO	10-Jan-91	montrose	18.5	80	7.4	9	19	100	500	300	700		100
CRO	08-Jan-91	kaapmuiden	36.6	100	7.2	7.7	8	100	500	300	1700		100
CRO	08-Jan-91	tenbosch	28.3	222	7.5	5.4	3.2	100	400	400	1700		200
CRO	10-Jan-91	rivuletts	18.8	78	7.4	9.1	24	100	400	300	500		100
CRO	09-Jan-91	hengel	20.9	92	7.5	12.4	6.4	100	600	600	900		100
CRO	10-Jan-91	croc_hot	19.3	80	7.4	11.6	27	100	600	300	500		100
CRO	10-Jan-91	mataffin	20.3	80	7.1	9.2	17	300	600	300	700		300
CRO	10-Jan-91	lions	22.4	100	7.4	7.1	37	100	800	400	900		100
CRO	12-Mar-91	rivside	26.1	200	7.8	7.5	12	60	200	100	800		100
CRO	12-Mar-91	tenbosch	26.9	220	7.7	6.2	10	89	300	200	600		101
CRO	13-Mar-91	lions	22.8	160	7.8	8.1	8	48	300	200	300		73
CRO	14-Mar-91	montrose	22.8	150	8	8.5	5	45	300	100	200		70
CRO	15-Mar-91	rivuletts	22.2	120	7.8	11.2	50	41	300	100	300		79
CRO	14-Mar-91	croc_hot	26.5	100	7.7	8.4	25	46	300	100	300		74
CRO	14-Mar-91	mataffin	21.8	150	7.5	8.1	5	41	1200	200	400		65
CRO	13-Mar-91	hengel	22.6	150	8.6	7.9	8	63	200	100	400		92
CRO	12-Mar-91	kaapmuiden	24.9	135	8	8	7	76	200	100	700		103
CRO	13-Sep-91	rivuletts	18.4	150	6.9	8.6	14	100	400	100	300		100
CRO	13-Sep-91	montrose	17.6	120	6.9	12.2	24	100	900	100	300		100
CRO	10-Sep-91	tenbosch	21.5	209	7.4	11.4	2	100	200	100	1300		100
CRO	10-Sep-91	kaapmuiden	22.3	300	7.3	13.2	3.5	100	300	100	1300		100
CRO	12-Sep-91	croc_hot	18.1	150	7.2	12.2	16	200	500	100	300		100
CRO	10-Sep-91	rivside	20.2	173	6.9	10.2	1.5	300	200	100	600		100
CRO	12-Sep-91	mataffin	18.2	150	6.9	8.5	7	100	200	100	300		100
CRO	11-Sep-91	hengel	18.8	170	6.7	11.8	5.5	100	300	100	1000		100
CRO	11-Sep-91	lions	18.8	112	9.1	8.5	6.5	100	300	100	300		200
CRO	04-Sep-92	mataffin						20		100		50	101
CRO	02-Sep-92	rivuletts	19.1	190	8.3			32		100		50	58
CRO	06-Sep-92	hengel	21.4	210	7.7			12		300		100	94
CRO	08-Sep-92	rivside	20.6	750	8.1			13		100		50	97
LET	22-Feb-90	pumpstation							0				
LET	22-Feb-90	nagude	28	160	6.9		28	65	7.5	71	281		
LET	22-Feb-90	camp16							211				
LET	22-Feb-90	junction											
LET	22-Feb-90	camp3	30	220	7.7		136	105	254	134	337		
LET	22-Feb-90	stab	29	200	7.8		136	117	628	140	318		
LET	22-Feb-90	nneska	27	160	7.6		47	89		154	263		

RIV	DATE	STATION	Na	K	Ca	Mg	SO_4	Cl	TDS	TSS	Alk	B	F	Al	As	Co	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn	Hg
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	g/l	µg/l
CRO	10-Oct-90	lions					17	7	104			1048								620	25	133		439	1
CRO	10-Oct-90	hengel					17	7	112			1065								800	25	778		1375	1
CRO	11-Oct-90	mataffin					17	7	119			1248								1410	25	330		922	3
CRO	09-Oct-90	rivside					41	22	204			1139								710	25	378		156	4
CRO	09-Oct-90	tenbosch					41	26	266.6			1096								2020	25	72		272	8
CRO	09-Oct-90	kaapmuiden					45	11	135			775								980	25	422		3450	5
CRO	12-Oct-90	rivuletts					16	6	117			927								480	25	45		694	1
CRO	10-Jan-91	montrose					59	48	116			487							12.5	4300	25	180		90	2
CRO	08-Jan-91	kaapmuiden					54	46	130.6			128							12.5	1700	25	660		900	0.5
CRO	08-Jan-91	tenbosch					82	47	155.9			196							12.5	900	25	160		1800	1
CRO	10-Jan-91	rivuletts					58	46	2787.9			60							12.5	2500	25	280		600	2
CRO	09-Jan-91	hengel					41	46	128			131							12.5	900	25	120		1100	0.5
CRO	10-Jan-91	croc_hot					48	46	99.9			220							12.5	5400	25	560		1000	0.5
CRO	10-Jan-91	mataffin					45	47	116			238							12.5	3600	25	500		50	1
CRO	10-Jan-91	lions					53	48	205.3			249							12.5	3300	25	210		60	1
CRO	12-Mar-91	rivside					13	9	91			97								50	25	12.5		12.5	2
CRO	12-Mar-91	tenbosch					16	15	215			89								70	25	12.5		730	1
CRO	13-Mar-91	lions					9	7	70			94								60	25	12.5		12.5	0.5
CRO	14-Mar-91	montrose					8	6	54			239								140	25	12.5		720	1
CRO	15-Mar-91	rivuletts					7	5	63			103								380	25	12.5		12.5	2
CRO	14-Mar-91	croc_hot					5	6	82			88								390	25	12.5		30	0.5
CRO	14-Mar-91	mataffin					9	7	73			118								180	25	40		710	0.5
CRO	13-Mar-91	hengel					10	6	112			87								130	25	12.5		350	2
CRO	12-Mar-91	kaapmuiden					10	7	84			92								70	25	12.5		40	0.5
CRO	13-Sep-91	rivuletts				7	9	7	15			104	100							550	25	30		12.5	0.5
CRO	13-Sep-91	montrose				6	11	2.5	13			212	100							2700	25	50		40	0.5
CRO	10-Sep-91	tenbosch				9	19	10	21			175	100		10					200	25	70		50	0.5
CRO	10-Sep-91	kaapmuiden				19	24	16	37			199	100		15					1010	25	50		50	0.5
CRO	12-Sep-91	croc_hot				8	8	7	15			201	100							700	25	40		40	0.5
CRO	10-Sep-91	rivside				20	23	22	45			206	100							680	25	40		50	0.5
CRO	12-Sep-91	mataffin				8	7	7	16			202	100							6150	25	80		40	0.5
CRO	11-Sep-91	hengel				7	16	7	13			199	100		2.5					440	25	1220		40	0.5
CRO	11-Sep-91	lions				7	8	7	15			194	100							500	25	40		40	0.5
CRO	04-Sep-92	mataffin	6			11		10	121							12.5	2.5		12.5	420	25	70	12.5	12.5	
CRO	02-Sep-92	rivuletts	5			10		13	121							12.5	2.5	15	12.5	530	25	40	12.5	12.5	
CRO	06-Sep-92	hengel	6			11		10	136							12.5	2.5	15	12.5	180	25	510	12.5	12.5	
CRO	08-Sep-92	rivside	68			32		39	419							12.5	2.5		12.5	150	25	110	12.5	12.5	
LET	22-Feb-90	pumpstation																							
LET	22-Feb-90	nagude																							
LET	22-Feb-90	camp16																							
LET	22-Feb-90	junction																							
LET	22-Feb-90	camp3																							
LET	22-Feb-90	stab																							
LET	22-Feb-90	nneska																							

RIV	DATE	STATION	oC	COND	pH	DO	NTU	ORT-P	KJEL-N	NH4-N	NO_2+NO3	NO3-N	TOT-P	Na	K	Ca	Mg	SO_4	Cl	TDS	TSS	Alk	B	F	Al	As	Cu	Cd	Cr	Co	Fe	Pb	Mn	Ni	Zn	Hg
				m S/cm				µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	g/l	µg/l
LET	22-Feb-90	mondwem					77	95	201	222	303																									
LET	22-Feb-90	mingerhout																																		
LET	22-Feb-90	prieskaf	29	160	7.7		116	69	230	86	307																									
LET	22-Feb-90	eng oli																																		
LET	22-Feb-90	engelhrt																																		
LET	22-Feb-90	letsitele																																		
LET	09-May-90	eng oli																																		
LET	09-May-90	prieska	21	270	7.4																															
LET	09-May-90	slab	22	330	8.1		24	47	200	62	301																									
LET	09-May-90	letsitele	22	50	7.6		3	32	199	92	274																									
LET	09-May-90	camp16	22	320	7.7		42	53	230	83	439																									
LET	09-May-90	nagude	21	270	7.8		25																													
LET	09-May-90	camp3	22	340	7.9		25																													
LET	09-May-90	engelhrt																																		
LET	09-May-90	junction	21	150	7.6		5	50	224	80	291																									
LET	09-May-90	prieskaf	23	270	8		18	41	169	67	303																									
LET	09-May-90	mingerhout																																		
LET	09-May-90	pumpstation	21	260	7.5		18	40	230	70	357																									
LET	09-May-90	mondweni	22	330	7.8																															
LET	08-Aug-90	slab	21	550	8		8	39	214	29	62																									
LET	08-Aug-90	nondweni	18	510	7.7																															
LET	08-Aug-90	letsitele	17	60	7.4		3	38	153	21	308			6	1	4	1	9	7			21														
LET	08-Aug-90	prieska	20	370	8.1																															
LET	08-Aug-90	pumpstation	20	300	7.2																															
LET	08-Aug-90	prieskaf	19	400	7.7		4	58	409	86	208																									
LET	08-Aug-90	eng oli																																		
LET	08-Aug-90	mingerhout																																		
LET	08-Aug-90	camp3	20	670	7.5																															
LET	08-Aug-90	camp16	20	660	7.7		10	52	386	84	94			37	2	33	11	6	65			151														
LET	08-Aug-90	engelhrt																																		
LET	08-Aug-90	nagude	18	230	7.3		10	60	263	48	563																									
LET	08-Aug-90	junction	17	110	7.7		20	82	302	75	446																									
LET	21-Nov-90	slab	29	580	8.3																															
LET	21-Nov-90	eng oli	26	320	7.5		22	103	437	105	91			41	2	18	14	6	47			144														
LET	21-Nov-90	camp3	29	610	8.2		20	36	259	98	79			56	2	24	16	39	81			113														
LET	21-Nov-90	mingerhout	37	440	8.6		15	91	337	76	93			22	2	18	11	6	23			128														
LET	21-Nov-90	mondwem	28	410	8		4	19	263	97	94			47	1	15	12	20	44			129														
LET	21-Nov-90	camp16	29	690	8.4																															
LET	21-Nov-90	engelhrt	27	480	7.6																															
LET	21-Nov-90	nagude	25	120	7.9																															
LET	21-Nov-90	prieskaf	27	230	8																															
LET	21-Nov-90	prieska	29	210	8.1																															
LET	21-Nov-90	junction	26	40	8.2		5	23	219	71	363			9	1	3	2	6	7			22														
LET	21-Nov-90	pumpstation	27	160	8.2																															
LET	21-Nov-90	letsitele	24	40	7.5		4	52	331	101	378			4	0.5	2	2	4	6			19														

RIV	DATE	STATION	oC	COND	pH	DO	NTU	ORT-P	KJEL-N	NH4-N	NO3+NO2	NO3-N	TOT-P	Na	K	Ca	Mg	SO4	Cl	TDS	TSS	Alk	B	F	Al	As	Co	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn	Hg
				m S/cm				µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	g/l	µg/l
LET	13-Feb-91	pumpstation	29	140	8.3		34	73		69	358			4	2	8	4	22	17			28														
LET	13-Feb-91	camp16	27	210	7.8		78	69	269	66	267			21	2	11	6	20	24			57														
LET	13-Feb-91	nondweni	27	210	7.9		27	56	231	51	213																									
LET	13-Feb-91	prieska	27	160	7.9		32		256																											
LET	13-Feb-91	eng_oli																																		
LET	13-Feb-91	slab					48							15	2	11	6	19	22			54														
LET	13-Feb-91	junction	26	120	7.9		67	70	315	187	313			10	3	9	3	23	15			29														
LET	13-Feb-91	engelhrt																																		
LET	13-Feb-91	camp3	27	190	8		39	63	228	62	235			14	2	9	6	8	20			53														
LET	13-Feb-91	mingerhout																																		
LET	13-Feb-91	prieskaf	26	180	7.9		29							9	2	12	6	27	18			42														
LET	13-Feb-91	letsitele	25	120	7.7		52	74	292	95	555			9	3	10	3	30	15			25														
LET	13-Feb-91	nagude	26	160	7.8		82																													
LET	22-May-91	pumpstation	20	260	7.8		3	80																												
LET	22-May-91	nagude	20	230	7.5		3																													
LET	22-May-91	camp16	21	270	7.8		7	93	321	56	57			29	2	16	10	5	38			96														
LET	22-May-91	mingerhout																																		
LET	22-May-91	junction	20	160	7.5		4	89	324	52	347			10	1	12	6	2.5	17			60														
LET	22-May-91	letsitele	19	70	7.9		2	85	269	57	362			4	1	5	2	2.5	11			22														
LET	22-May-91	engelhrt																																		
LET	22-May-91	camp3	21	340	7.7		5	86	298	58	182																									
LET	22-May-91	nondweni	21	330	7.8		4	76	266	50	164																									
LET	22-May-91	slab	23	310	8		2							32	2	17	10	2.5	42			100														
LET	22-May-91	prieska	20	270	7.7		6																													
LET	22-May-91	eng_oli																																		
LET	22-May-91	prieskaf	21	260	7.8		2							23	1	17	10	2.5	35			87														
LET	20-Aug-91	letsitele	17	50	7.7																															
LET	20-Aug-91	nondweni	19	390	7.8		8	32	406	49	156			51	1	20	13	24	53			139														
LET	20-Aug-91	prieskaf	18	220	7.8		4	39	403	51	245			23	0.5	15	8	13	31			84														
LET	20-Aug-91	engelhrt	18	300	7.8		27		602	109	390			28	1	22	12	5	34			124														
LET	20-Aug-91	mingerhout	18	330	7.9																															
LET	20-Aug-91	prieska	19	210	7.8		3	38	518	69	209			32	0.5	14	18	10	29			77														
LET	20-Aug-91	pumpstation	18	170	7.6		10	34																												
LET	20-Aug-91	slab	20	440	8		5	30	396	25	132			54	0.5	22	14	14	62			137														
LET	20-Aug-91	camp3	18	520	7.8		3	40	396	50	180			63	1	27	19	9	76			203														
LET	20-Aug-91	eng_oli	24	340	8			44																												
LET	20-Aug-91	camp16	19	410	7.8		3	223	462	74	160			46	1	22	13	7	58			133														
LET	20-Aug-91	nagude	18	190	7.2		10	41																												
LET	20-Aug-91	junction	19	120	7.4																															
LET	11-Nov-91	eng_oli																																		
LET	11-Nov-91	letsitele	21	50	7.7																															
LET	11-Nov-91	nagude	24	80	7.8																															
LET	11-Nov-91	prieska	27	170	8.1																															
LET	11-Nov-91	prieskaf	30	180	8									14	0.5	8	4	0.5	19			57														
LET	11-Nov-91	junction	29	120	7.7									11	0.5	4	2	5	9			37														

RIV	DATE	STATION	oC	COND	pH	DO	NTU	ORT-P	KJEL-N	NH4-N	NO_2+NO_3	NO3-N	TOT-P	Na	K	Ca	Mg	SO_4	Cl	TDS	TSS	Alk	B	F	Al	As	Co	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn	Hg
				m S/cm				µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	g/l	µg/l
LET	11-Nov-91	nondweni	28	210	7.8																															
LET	11-Nov-91	slab	30	220	8									19	0.5	9	5	5	24			71														
LET	11-Nov-91	engellm																																		
LET	11-Nov-91	pumpstation	28	140	8.1																															
LET	11-Nov-91	camp3	31	260	7.6																															
LET	11-Nov-91	camp16	28	270	8.1									23	0.5	10	7	6	31			85														
LET	11-Nov-91	mingerhout																																		
LET	12-May-93	midlet	21.9	160	8.3	.		400		100	500	50	400	8			5		6		13				394			2.5		40	470	25	50	12.5	100	
LET	12-May-93	hudson	23	130	7.2			300		100	700	50	600	8			4		6		52				576			2.5		40	760	25	80	12.5	80	
OLI	23-Jun-92	selpost	18.5	2400	8.5			600		1700	2000	100	600	162			138		162	1813							12.5	2.5	15	30	160	25	120	12.5	30	
OLI	23-Jun-92	selpre	21.3	440	8.7	[illegible]		100		500	200	50	100	34			27		43	306							12.5	2.5	15	12.5	110	25	50	12.5	30	
OLI	17-Feb-93	klipspruit	20.5	390	3.8	7.5		100		100	100		200	39	7	13	8	112	21	260		2.5			1887		30	2.5	15	12.5	260	25	560	12.5	12.5	
OLI	17-Feb-93	oliklip	22.4	180	7.6	5.9		100		100	100		300	14	5	11	5	56	11	135		29			495		12.5	2.5	15	12.5	490	25	100	12.5	12.5	
OLI	07-Jun-93	selati	12.9	1890	8.3	8.3		100		500	3700	700	300	132			146		131	1620							12.5	2.5	15	40	330	25	60	12.5	60	
OLI	09-Jun-93	haluli	21.6	1107	8.3	11.2																														
OLI	07-Jun-93	meetwal	19.6	2100	8.6	8		200		500	500	50	300	175			152		76	1800							30	2.5	15	120	320	25	230	12.5	280	
OLI	04-Nov-93	arabie	26	43	7.8																															
SAB	25-May-92	weir	18.6	150	7.8	8.6		100		300			200	4			6	18	2.5	84	6.9				275	2.5		6	15	12.5	170	25	40	12.5	12.5	
SAB	02-Jun-93	weir	20	90	7.6	10.5		100		300	300	50	300	5			3	18	5	53	10				219			2.5	15		190		12.5		70	
LEV	19-Aug-92	farm	15.5	230	7.9	7.5		30		300		50	93	24			12		31	137.3							12.5	2.5	15	60	210	25	40	12.5	90	
LEV	19-Aug-92	settlemnt	18.9	220	8.7	6.3		62		200		50	148	14			11		18	146.7							12.5	2.5	15	90	1310	25	420	12.5	160	
LEV	18-Aug-92	makuyup	19.9	250	8.5	6.4		567		900		500	733	16			7		17	148							12.5	2.5	15	60	300	25	500	12.5	180	
LEV	21-Jul-93	farm	16.8	180	7.8	6																														
LEV	21-Jul-91	settlemnt	18.5	120	7.4	7.6		100		100		50	200	7			2		7	100							12.5	2.5	15	12.5	770	25	70	12.5	70	
LEV	21-Jul-93	makuyup	20.6	120	7.4	9.9		100		100		50	200	10			2		10	95							12.5	2.5	15	80	400	25	40	40	190	
LEV	21-Jul-93	makuydn	19.4	140	7.6	8.8		100		100		50	100	8			2		10	83							12.5	2.5	15	80	480	25	40	30	160	

Appendix B
Fish Data

Appendix B1: Fish Biology Data

River	Date	spp	Site	Length	Mass	Gender	GI	Age
BER	26-Oct-92	Cc	VOELVLEI	510	3750	1	6	8
BER	26-Oct-92	Cc	VOELVLEI	495	3400	1	6	4
BER	26-Oct-92	Cc	VOELVLEI	470	2650	1	6	3
BER	26-Oct-92	Cc	VOELVLEI	460	2600	1	6	4
BER	26-Oct-92	Cc	VOELVLEI	455	3000	1	6	8
BER	05-Oct-93	Cc	MISVERST	455	2800	2	4.5	
BER	26-Oct-92	Cc	VOELVLEI	435	2250	1	6	4
BER	05-Oct-93	Om	MISVERST	215	446	2	4	
BER	26-Oct-92	Cc	VOELVLEI	420	2500	2	5	4
BER	26-Oct-92	Om	MISVERST	218	325	1	5	
BER	26-Oct-92	Om	MISVERST	220	258	2	5	
BER	26-Oct-92	Om	MISVERST	220	350	2	6	
BER	26-Oct-92	Om	MISVERST	240	450	2	6	
BER	05-Oct-93	Om	MISVERST	245	587	1	4	1.5
BER	05-Oct-93	Om	MISVERST	245	650	1	4	2.5
BER	05-Oct-93	Om	MISVERST	245	576	1	4	2
BER	05-Oct-93	Om	MISVERST	246	669	1	4	2
BER	26-Oct-92	Om	VOELVLEI	260	550	1	5	4
BER	05-Oct-93	Om	MISVERST	284	845	2	4.5	3
BER	05-Oct-93	Cc	MISVERST	290	599	1	2	
BER	05-Oct-93	Ms	MISVERST	330	1143	1	4	2
BER	05-Oct-93	Cc	MISVERST	334	732	2	4	
BER	26-Oct-92	Om	MISVERST	210	260	2	5	
BER	26-Oct-92	Om	MISVERST	200	220	2	4	
BER	26-Oct-92	Cc	VOELVLEI	398	1800	1	6	4
BER	05-Oct-93	Cc	VOELVLEI	390	2030	2	4	
BER	05-Oct-93	Md	VOELVLEI	348	923	2	5	3
BER	26-Oct-92	Om	MISVERST	353	520	1	5	
CRO	09-Oct-90	Tr	TENBOSCH	94	350	2	3	
CRO	11-Oct-90	Pp	MONTROSE	24	4.2			
CRO	11-Oct-90	Pp	MONTROSE	34	3.3			
CRO	11-Oct-90	Pp	MONTROSE	33	2.4			
CRO	11-Oct-90	Pp	MONTROSE	32	2.8			
CRO	11-Oct-90	Pp	MONTROSE	31	2.3			
CRO	11-Oct-90	Pp	MONTROSE	31	2.9			
CRO	11-Oct-90	Pp	MONTROSE	29	4.9			
CRO	11-Oct-90	Pp	MONTROSE	29	2.6			
CRO	11-Oct-90	Pp	MONTROSE	28	4.2			
CRO	11-Oct-90	Pp	MONTROSE	27	2.2			
CRO	11-Oct-90	Pp	MONTROSE	27	1.8			
CRO	11-Oct-90	Pp	MONTROSE	26	3.6			
CRO	11-Oct-90	Pp	MONTROSE	25	2.1			
CRO	11-Oct-90	Pp	MONTROSE	24	4.2			
CRO	11-Oct-90	Pp	MONTROSE	38	4.2			
CRO	09-Jan-91	Bm	HNGEL_CL	72				
CRO	09-Oct-90	Tr	TENBOSCH	92	325	1	3	
CRO	11-Oct-90	C	CROC_HOT	500	1550	1	2	
CRO	13-Sep-89	C	LIONS_CL	525	1600	1	4	
CRO	13-Sep-89	C	LIONS_CL	525	1780	1	5	
CRO	09-Oct-90	Bm	RVERSIDE	251	450	2	6	
CRO	09-Oct-90	Lc	RVERSIDE	251	525	1	2	
CRO	09-Oct-90	Bm	RVERSIDE	251	475	1	2	2
CRO	09-Oct-90	Bm	RVERSIDE	251	450	2	5	
CRO	16-Sep-92	Tr	TENBOSCH	270	1024	1	4	
CRO	12-Jun-90	Lr	TENBOSCH	250	330	2	2	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	16-Sep-92	C	LIONS_CL	415	750	2	4	3
CRO	16-Sep-92	C	LIONS_CL	420	1000	2	2	3
CRO	16-Sep-92	C	LIONS_CL	470	1200	2	3	5
CRO	16-Sep-92	C	MATAFFIN	550	2200	2	2	3
CRO	16-Sep-92	C	MATAFFIN	620	3000	2	2	2
CRO	10-Oct-90	C	LIONS_CL	867	7550	1	5	8
CRO	15-Jun-89	C	LIONS_CL	865	6650	1	5	
CRO	13-Jun-90	C	LIONS_CL	841	7250	1	3	10
CRO	14-Jun-89	C	RVERSIDE	810	6350	1	5	
CRO	15-Jun-89	C	LIONS_CL	805	5850	1	5	
CRO	14-Jun-89	C	RVERSIDE	685	4120	1	2	
CRO	11-Jan-90	C	MATAFFIN	665	2930	1	5	
CRO	13-Sep-89	C	TENBOSCH	655	3260	1	5	
CRO	08-Mar-90	C	RVULETTS	655	3200	2	5	
CRO	13-Sep-89	C	LIONS_CL	645	2640	1	4	
CRO	12-Oct-90	C	RVULETTS	632	2650	1	4	5
CRO	10-Jan-90	C	RVERSIDE	632	2640	1	4	
CRO	09-Oct-90	Lc	RVERSIDE	250	450	1	3	
CRO	13-Jun-90	C	LIONS_CL	631	2250	1	3	4
CRO	13-Sep-89	C	HNGEL_CL	627	2520	1	4	
CRO	12-Oct-90	C	RVULETTS	625	2600	1	4	
CRO	11-Oct-90	C	CROC_HOT	625	2675	1	4	
CRO	13-Jun-89	C	TENBOSCH	624	2420	1	2	
CRO	12-Oct-90	C	RVULETTS	624	2725	1	4	4
CRO	12-Oct-90	C	RVULETTS	619	2700	1	4	
CRO	10-Sep-91	Si	RVERSIDE	250	250	2	3	
CRO	09-Oct-90	Lc	RVERSIDE	250	500	1	2	
CRO	12-Oct-90	C	RVULETTS	609	2400	2	4	
CRO	15-Jun-89	C	LIONS_CL	605	2260	1	3	
CRO	08-Mar-90	C	RVULETTS	600	2420	2	5	
CRO	11-Oct-90	C	CROC_HOT	600	2350	2	3	2
CRO	12-Oct-90	C	RVULETTS	598	2180	2	2	
CRO	15-Jun-89	C	MATAFFIN	587	2260	2	5	
CRO	06-Mar-90	C	TENBOSCH	585	1950	2	2	
CRO	12-Oct-90	C	RVULETTS	580	1900	1	4	
CRO	12-Oct-90	C	RVULETTS	580	2050	2	3	4
CRO	15-Jun-89	C	LIONS_CL	580	2300	1	4	
CRO	11-Oct-90	C	CROC_HOT	575	2400	1	4	
CRO	12-Oct-90	C	RVULETTS	573	1850	1	4	
CRO	11-Oct-90	C	CROC_HOT	570	1750	1	3	
CRO	13-Mar-91	C	HNGEL_CL	566	1850	1	5	
CRO	11-Jan-90	C	MATAFFIN	565	2200	1	3	
CRO	12-Oct-90	C	RVULETTS	564	1950	2	3	4
CRO	15-Jun-89	C	LIONS_CL	563	2080	1	4	
CRO	11-Oct-90	C	CROC_HOT	560	2050	1	3	2
CRO	11-Oct-90	C	CROC_HOT	560	1900	1	4	4
CRO	12-Oct-90	C	RVULETTS	558	2000	2	4	
CRO	13-Jun-90	C	LIONS_CL	558	1650	1	3	
CRO	06-Mar-90	C	CROC_HOT	550	2010	2	5	
CRO	13-Mar-91	C	HNGEL_CL	548	1700	2	2	
CRO	13-Mar-91	C	LIONS_CL	545	2300	2	2	
CRO	13-Mar-91	C	HNGEL_CL	543	1700	2	2	
CRO	13-Sep-89	C	LIONS_CL	535	1400	1	2	
CRO	10-Jan-90	C	LIONS_CL	535	1720	1	4	
CRO	12-Jan-90	C	CROC_HOT	534	1750	2	4	
CRO	13-Sep-89	C	HNGEL_CL	532	1660	1	5	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	13-Jun-90	C	HNGEL_CL	532	1475	1		
CRO	13-Sep-89	C	HNGEL_CL	531	1460	1	5	
CRO	12-Oct-90	C	RVULETTS	530	1500	1	2	
CRO	15-Jun-89	C	LIONS_CL	530	1560	1	4	
CRO	13-Sep-89	C	HNGEL_CL	528	1260	1	2	
CRO	13-Sep-89	C	TENBOSCH	525	1640	1	5	
CRO	12-Oct-90	C	RVULETTS	525	1700	1	3	
CRO	14-Sep-89	C	RVERSIDE	525	1760	2	2	
CRO	14-Jun-89	C	RVERSIDE	525	1620	2	2	
CRO	09-Jan-90	C	TENBOSCH	522	1620	2	4	
CRO	12-Oct-90	C	RVULETTS	522	1700	2	4	
CRO	11-Oct-90	C	CROC_HOT	520	1200	2	3	
CRO	12-Oct-90	C	RVULETTS	519	1750	2	4	
CRO	12-Oct-90	C	RVULETTS	518	1800	1	4	4
CRO	12-Oct-90	C	RVULETTS	515	1850	2	2	4
CRO	13-Mar-91	C	HNGEL_CL	514	1650	1	5	
CRO	09-Mar-90	C	MATAFFIN	512	2800	1	5	
CRO	15-Jun-89	C	LIONS_CL	512	1330	1	5	
CRO	13-Jun-90	C	LIONS_CL	510	1350	1	3	
CRO	10-Sep-91	Tr	TENBOSCH	249	830	2	3	
CRO	13-Jun-90	C	HNGEL_CL	510	1560	1		3
CRO	12-Oct-90	C	RVULETTS	508	1450	2	3	
CRO	13-Jun-90	C	LIONS_CL	505	1350	2	2	
CRO	13-Sep-89	C	LIONS_CL	503	1400	1	4	
CRO	09-Oct-90	Bm	RVERSIDE	249	400	2	5	3
CRO	09-Jan-91	C	HNGEL_CL	498	1410	1	4	2
CRO	13-Jun-90	C	HNGEL_CL	497	1050	1	4	2
CRO	09-Oct-90	Bi	RVERSIDE	178	170	2	5	2
CRO	11-Oct-90	C	HNGEL_CL	500	1450	2	3	3
CRO	13-Jun-90	C	HNGEL_CL	496	1460	2	2	2
CRO	13-Mar-91	C	HNGEL_CL	496	1420	1	3	
CRO	11-Oct-90	C	CROC_HOT	496	1450	1	3	2
CRO	11-Oct-90	C	CROC_HOT	495	1200	1	2	2
CRO	15-Jun-89	C	LIONS_CL	494	1320	1	3	
CRO	13-Sep-89	C	HNGEL_CL	490	1100	1	2	
CRO	09-Oct-90	Lc	TENBOSCH	482	2060	2	5	3
CRO	10-Oct-90	C	LIONS_CL	482	1325	2	3	3
CRO	11-Oct-90	C	HNGEL_CL	482	1200	1	5	2
CRO	13-Jun-90	C	LIONS_CL	481	1440	2		
CRO	13-Sep-89	C	HNGEL_CL	478	1340	1	4	
CRO	07-Mar-90	Om	LIONS_CL	181	185	1	4	2
CRO	13-Jun-90	C	LIONS_CL	484	1425	2		
CRO	13-Mar-91	C	HNGEL_CL	478	1290	1	4	
CRO	13-Sep-89	Bm	HNGEL_CL	182	160	1	1	
CRO	07-Mar-90	C	LIONS_CL	506	1510	1	4	
CRO	13-Mar-91	C	HNGEL_CL	478	1150	1	2	
CRO	13-Jun-90	C	LIONS_CL	477	1150	1	3	4
CRO	13-Mar-91	C	HNGEL_CL	476	1190	1	3	
CRO	14-Sep-89	C	RVERSIDE	475	1380	2	5	
CRO	15-Jun-89	C	LIONS_CL	475	1320	1	4	
CRO	13-Jun-90	C	LIONS_CL	475	1100	1		
CRO	10-Jan-90	C	LIONS_CL	475	1350	2	4	
CRO	07-Mar-90	C	HNGEL_CL	475	1120	1	4	
CRO	11-Oct-90	C	CROC_HOT	475	1300	1	3	2
CRO	07-Mar-90	C	HNGEL_CL	474	1170	2	4	
CRO	10-Oct-90	C	LIONS_CL	473	1175	2	2	4
CRO	13-Sep-89	C	HNGEL_CL	473	1170	1	4	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	15-Jun-89	C	LIONS_CL	472	1300	1	4	
CRO	13-Sep-89	C	HNGEL_CL	471	1260	2	2	
CRO	09-Oct-90	Lc	RVERSIDE	249	400	1	1	2
CRO	13-Sep-89	C	HNGEL_CL	463	1100	2	3	
CRO	13-Jun-90	C	LIONS_CL	462	1075	1		
CRO	13-Sep-89	C	LIONS_CL	461	1060	1	4	
CRO	10-Jan-90	C	RVERSIDE	460				
CRO	13-Jun-90	C	LIONS_CL	460	1250	2		
CRO	12-Jun-90	C	RVERSIDE	459	1320	2	1	3
CRO	10-Jan-90	C	LIONS_CL	459	1160	2	4	
CRO	12-Jun-90	C	RVERSIDE	457	1260	2	2	4
CRO	16-Sep-92	Bm	RVULETTS	456	2700	2	5	5
CRO	10-Jan-90	C	LIONS_CL	456	1240	2	4	3
CRO	10-Sep-91	C	RVERSIDE	455	1050	1	4	3
CRO	10-Jan-90	C	LIONS_CL	455	1210	2	4	
CRO	13-Jun-90	C	LIONS_CL	453	980	2		
CRO	15-Jun-89	C	LIONS_CL	452	1220	2	6	
CRO	13-Sep-89	C	HNGEL_CL	451	1200	2	2	
CRO	13-Mar-91	C	HNGEL_CL	451	910	1	3	
CRO	12-Jun-90	Sz	TENBOSCH	190	125	2	1	2
CRO	12-Jun-90	Tr	TENBOSCH	190	310	1	1	2
CRO	13-Mar-91	C	RVERSIDE	450	1100	2	2	
CRO	13-Mar-91	C	HNGEL_CL	449	1050	1	4	
CRO	09-Oct-90	Bi	RVERSIDE	192	200	2	5	2
CRO	08-Jan-91	C	TENBOSCH	467	1100	1	4	3
CRO	13-Sep-89	C	HNGEL_CL	448	860	2	2	
CRO	15-Jun-89	C	LIONS_CL	444	833	2	2	
CRO	13-Jun-90	C	HNGEL_CL	442	980	2		
CRO	13-Sep-89	Bm	HNGEL_CL	194	200	1	3	
CRO	08-Mar-90	C	CROC_HOT	443	1150	1	3	
CRO	13-Sep-89	C	TENBOSCH	435	1120	2	3	
CRO	14-Sep-89	C	RVERSIDE	435	1140	2	4	
CRO	10-Jan-90	C	RVERSIDE	435	1100	2	4	
CRO	10-Jan-90	C	LIONS_CL	435	1040	2	4	
CRO	15-Jun-89	C	LIONS_CL	426	820	2	2	
CRO	11-Jan-90	C	MATAFFIN	425	1000	2	2	
CRO	13-Sep-89	C	HNGEL_CL	424	800	1	3	
CRO	13-Jun-90	C	HNGEL_CL	424	830	1		
CRO	06-Mar-90	Si	RVERSIDE	249	220	2	3	3
CRO	15-Jun-89	C	LIONS_CL	422	845	2	2	
CRO	13-Sep-89	C	HNGEL_CL	421	820	2	3	
CRO	12-Jun-90	Lc	TENBOSCH	420	2500	2	3	3
CRO	14-Jun-90	Bm	RVULETTS	195	150	1	3	3
CRO	13-Jun-90	C	HNGEL_CL	419	810	2		
CRO	13-Jun-90	C	HNGEL_CL	418	710	2		
CRO	13-Jun-90	C	HNGEL_CL	417	840	2	1	1
CRO	12-Sep-91	Bm	CROC_HOT	249	370	1	2	3
CRO	14-Jun-89	Bm	RVERSIDE	416	1780	2	2	
CRO	11-Sep-91	C	HNGEL_CL	415	850	2	2	
CRO	14-Mar-91	C	MATAFFIN	413	980	2	2	
CRO	08-Jan-91	C	TENBOSCH	411	850	1	4	5
CRO	14-Mar-91	C	MATAFFIN	411	950	2	2	
CRO	13-Sep-89	C	HNGEL_CL	402	820	2	4	
CRO	14-Mar-91	Bm	CROC_HOT	198	150	1	3	
CRO	14-Jun-89	Bm	RVERSIDE	410	1220	2		
CRO	09-Oct-90	Lc	TENBOSCH	400	2100	2	5	2

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	11-Sep-91	C	LIONS_CL	400	800	1	2	4
CRO	13-Sep-89	Bm	HNGEL_CL	400	1800	2	4	
CRO	06-Mar-90	Lc	TENBOSCH	395	1480	2	2	
CRO	10-Sep-91	Om	TENBOSCH	248	650	2	4	5
CRO	11-Jan-90	C	HNGEL_CL	393	690	2	5	
CRO	09-Oct-90	C	RVERSIDE	391	800	1	4	2
CRO	11-Sep-91	C	HNGEL_CL	391	620	1	1	2
CRO	13-Sep-89	C	HNGEL_CL	390	620	1	1	
CRO	12-Jun-90	Lc	TENBOSCH	389	2025	2	7	
CRO	09-Oct-90	Bm	RVERSIDE	248	400	1	5	
CRO	09-Oct-90	Lc	TENBOSCH	388	1775	2	5	2
CRO	13-Sep-89	C	HNGEL_CL	381	1180	2	4	
CRO	09-Jan-91	C	HNGEL_CL	381	610	2	4	3
CRO	12-Jun-90	Om	TENBOSCH	246	650	1	4	4
CRO	10-Jan-90	C	LIONS_CL	380	590	1	3	
CRO	11-Sep-91	C	LIONS_CL	379	700	2	2	3
CRO	11-Jan-90	C	HNGEL_CL	379	640	2	5	
CRO	08-Jan-91	Lc	TENBOSCH	378	1350	1	5	5
CRO	14-Sep-89	Lm	RVERSIDE	376	1680	2	4	
CRO	10-Jan-90	Lc	RVERSIDE	375	1240	2	2	
CRO	14-Jun-90	Bm	RVULETTS	246	320	2	4	3
CRO	12-Jun-90	Tr	TENBOSCH	201	325	1	2	3
CRO	11-Sep-91	C	LIONS_CL	375	650	1	3	4
CRO	13-Sep-89	Lm	HNGEL_CL	376	1080	2	5	
CRO	14-Jun-89	Bm	RVERSIDE	368	1140	2	2	
CRO	10-Sep-91	Lc	TENBOSCH	366	1300	2	2	3
CRO	11-Jan-90	Lm	MATAFFIN	366	1180	2	4	
CRO	13-Sep-89	Bm	LIONS_CL	366	1250	2	5	
CRO	14-Jun-89	Bm	RVERSIDE	365	1120	2	5	
CRO	14-Jun-89	Bm	RVERSIDE	365	1200	2	1	
CRO	14-Jun-89	Bm	RVERSIDE	365	1240	2		
CRO	14-Jun-89	Bm	RVERSIDE	365	1300	2	2	
CRO	10-Jan-90	Bm	RVERSIDE	365				
CRO	10-Sep-91	C	TENBOSCH	364	600	2	1	
CRO	14-Jun-90	Bm	RVULETTS	203	175	1	3	4
CRO	09-Jan-91	Bm	HNGEL_CL	204	210	1	2	
CRO	09-Jan-91	Bm	HNGEL_CL	204	170	2	2	
CRO	14-Jun-89	Bm	RVERSIDE	380	1340	2		
CRO	14-Jun-89	Bm	RVERSIDE	371	1300	2		
CRO	14-Jun-89	Bm	RVERSIDE	360	1100	2	3	
CRO	12-Sep-91	Bm	CROC_HOT	360	1200	2	5	3
CRO	09-Oct-90	Bm	TENBOSCH	356	1150	2	4	3
CRO	08-Jan-91	Lc	TENBOSCH	356	1300	2	5	5
CRO	13-Sep-89	C	HNGEL_CL	356	480	2	2	
CRO	13-Sep-89	Om	TENBOSCH	355	1560	1	6	
CRO	10-Sep-91	Lc	TENBOSCH	355	1200	2	2	3
CRO	06-Mar-90	C	RVERSIDE	355	520	1	2	
CRO	12-Oct-90	Bm	RVULETTS	350	1100	2	2	2
CRO	09-Mar-90	Bm	MATAFFIN	350	1120	2	4	4
CRO	11-Oct-90	Bm	CROC_HOT	349	1450	2	5	3
CRO	09-Jan-90	Lc	TENBOSCH	346	1130	1	5	
CRO	14-Jun-90	Bm	RVULETTS	205	150	1	3	
CRO	11-Jan-90	C	HNGEL_CL	355	460	2	2	
CRO	15-Jun-89	C	LIONS_CL	345	410	2	2	
CRO	13-Sep-89	Om	TENBOSCH	205	380	1	2	
CRO	12-Mar-91	Lr	TENBOSCH	345	1060	2	2	
CRO	13-Mar-91	Bm	RVERSIDE	344	1100	2	5	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	14-Jun-90	Bm	RVULETTS	206	175	1	1	2
CRO	13-Sep-89	C	HNGEL_CL	382	810	2	2	
CRO	13-Jun-90	C	HNGEL_CL	341	420	2		
CRO	14-Sep-89	Bm	RVERSIDE	340	1000	2	5	
CRO	09-Oct-90	Bm	RVERSIDE	208	250	1	2	
CRO	09-Jan-90	Om	TENBOSCH	342	1324	1	5	3
CRO	13-Sep-89	Om	TENBOSCH	335	1280	1	5	
CRO	14-Jun-90	Bm	RVULETTS	209	175	1	1	
CRO	06-Mar-90	Lc	TENBOSCH	389	1360	2	2	
CRO	11-Sep-91	C	LIONS_CL	335	500	1	1	2
CRO	06-Mar-90	Tr	TENBOSCH	209	350	1	3	2
CRO	11-Jan-90	Bm	HNGEL_CL	210	200	1	3	
CRO	13-Sep-89	Bm	HNGEL_CL	210	260	1	3	
CRO	13-Mar-91	C	HNGEL_CL	420	720	2	4	
CRO	13-Jun-89	Om	TENBOSCH	334	1360	1	5	
CRO	13-Sep-89	Bm	HNGEL_CL	334	900	2	3	
CRO	13-Jun-90	C	HNGEL_CL	334	360	2	1	2
CRO	14-Mar-91	C	CROC_HOT	334	410	1	2	
CRO	13-Jun-90	C	HNGEL_CL	400	800			
CRO	10-Oct-90	Lm	LIONS_CL	331	975	1	5	3
CRO	09-Oct-90	Lc	RVERSIDE	330	1075	2	5	2
CRO	13-Sep-89	C	HNGEL_CL	330	340	2	1	
CRO	11-Oct-90	Bm	CROC_HOT	330	1250	2	5	2
CRO	13-Jun-89	Hv	TENBOSCH	329	540	1	1	
CRO	12-Oct-90	Lm	RVULETTS	328	1000	2	4	2
CRO	13-Jun-89	Om	TENBOSCH	327	1340	1	5	
CRO	12-Mar-91	Lr	TENBOSCH	327	800	1	3	
CRO	12-Jan-90	Bm	CROC_HOT	327	985	2	5	
CRO	15-Jun-89	C	LIONS_CL	325	395	1	1	
CRO	09-Jan-91	C	HNGEL_CL	322	420	1	1	2
CRO	13-Sep-89	C	HNGEL_CL	320	310	1	2	
CRO	13-Sep-89	Tr	TENBOSCH	210	480	2	4	
CRO	09-Jan-90	Om	TENBOSCH	321	1220	1	5	4
CRO	12-Jun-90	Tr	RVERSIDE	211	460	1	2	5
CRO	11-Oct-90	Bm	CROC_HOT	323	1050	2	4	3
CRO	09-Jan-91	Bm	HNGEL_CL	212	225	1	4	4
CRO	14-Jun-89	Bm	RVERSIDE	330	860	2	1	
CRO	14-Sep-89	Bm	CROC_HOT	320	855	2	5	
CRO	09-Oct-90	Om	TENBOSCH	319	1075	1	4	4
CRO	13-Jun-89	Om	TENBOSCH	319	1220	2	5	
CRO	06-Mar-90	Lc	RVERSIDE	212	225	1	2	
CRO	15-Mar-91	C	RVULETTS	420	0	1	2	
CRO	12-Mar-91	Hv	TENBOSCH	319	750	1	2	
CRO	14-Mar-91	Bm	CROC_HOT	213	210	1	5	
CRO	13-Jun-90	C	HNGEL_CL	432	1000	2	2	3
CRO	11-Jan-90	Bm	MATAFFIN	319	800	2	4	
CRO	09-Jan-90	Om	TENBOSCH	316	965	1	5	4
CRO	09-Oct-90	Bm	RVERSIDE	213	400	1	2	
CRO	14-Jun-90	Bm	RVULETTS	213	200	1	4	
CRO	13-Sep-89	Bm	HNGEL_CL	214	240	1	5	
CRO	13-Sep-89	Bm	HNGEL_CL	214	260	1	3	
CRO	12-Oct-90	C	RVULETTS	510	1600	2	2	
CRO	12-Jun-90	C	TENBOSCH	522	2025	2	3	3
CRO	08-Jan-91	Lm	TENBOSCH	214	280	2	1	3
CRO	12-Jun-90	Om	TENBOSCH	214	325	2	2	4
CRO	09-Jan-91	Lm	HNGEL_CL	215	225	1	5	2

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	14-Jun-89	C	RVERSIDE	530	1620	1	3	
CRO	13-Sep-89	Tr	TENBOSCH	315	1440	2	4	
CRO	13-Jun-89	Om	TENBOSCH	313	1140	1	4	
CRO	10-Oct-90	Lm	LIONS_CL	313	725	1	3	2
CRO	08-Mar-90	Lm	CROC_HOT	313	960	2	5	2
CRO	10-Sep-91	Lc	RVERSIDE	312	750	1	2	5
CRO	09-Jan-90	Om	TENBOSCH	311	1130	1	4	
CRO	14-Jun-89	Lm	RVERSIDE	311	700	2	6	
CRO	13-Sep-89	Om	TENBOSCH	310	1200	1	5	
CRO	09-Oct-90	Bm	TENBOSCH	308	750	1	2	3
CRO	10-Sep-91	Bm	RVERSIDE	215	200	1	2	
CRO	13-Sep-89	C	HNGEL_CL	542	1680	1	5	
CRO	07-Mar-90	Bm	LIONS_CL	307	790	2	4	3
CRO	12-Jun-90	Tr	TENBOSCH	215	475	2	2	4
CRO	09-Jan-91	Bm	HNGEL_CL	216	225	1	4	4
CRO	13-Sep-89	Bm	HNGEL_CL	216	220	1	5	
CRO	09-Oct-90	C	RVERSIDE	580	2200	1	5	4
CRO	14-Sep-89	Lm	CROC_HOT	306	730	1	4	
CRO	09-Jan-90	Tr	TENBOSCH	305	1280	1	3	3
CRO	09-Jan-90	Tr	TENBOSCH	305	1400	1	4	3
CRO	10-Sep-91	Lc	RVERSIDE	305	650	1	1	2
CRO	10-Sep-91	Lm	RVERSIDE	305	700	1	4	3
CRO	09-Jan-91	Lm	HNGEL_CL	304	770	1	5	3
CRO	13-Mar-91	Bm	RVERSIDE	303	960	1	6	
CRO	11-Jan-90	Bm	HNGEL_CL	220	260	1	3	
CRO	13-Sep-89	Bm	HNGEL_CL	220	280	1	4	
CRO	11-Oct-90	C	HNGEL_CL	618	2950	1	2	3
CRO	14-Jun-89	C	RVERSIDE	623	2780	2	1	
CRO	10-Oct-90	Lm	LIONS_CL	303	850	1	5	4
CRO	14-Sep-89	Bm	CROC_HOT	303	720	1	4	
CRO	13-Mar-91	Bm	RVERSIDE	302	640	1	3	
CRO	09-Oct-90	Tr	TENBOSCH	301	1480	1	5	
CRO	12-Jun-90	Lc	TENBOSCH	300	750	2	2	
CRO	11-Sep-91	C	LIONS_CL	300	300	1	1	1
CRO	12-Mar-91	Om	TENBOSCH	299	1120	2	3	
CRO	10-Sep-91	Om	TENBOSCH	298	1050	1	4	6
CRO	14-Sep-89	Lm	RVERSIDE	298	630	2	1	
CRO	13-Mar-91	Lm	HNGEL_CL	297	650	2	4	
CRO	13-Sep-89	Om	TENBOSCH	295	880	2	5	
CRO	14-Jun-90	Lm	RVULETTS	295	700	1	4	2
CRO	10-Sep-91	Lr	RVERSIDE	295	850	2	2	4
CRO	13-Sep-89	C	HNGEL_CL	556	1820	1	5	
CRO	06-Mar-90	Sz	RVERSIDE	295	200	2	5	
CRO	10-Sep-91	Om	TENBOSCH	294	940	1	5	5
CRO	14-Jun-90	Bm	RVULETTS	220	200	1	2	
CRO	11-Sep-91	C	LIONS_CL	300	350	1	1	1
CRO	14-Jun-90	Lm	RVULETTS	294	700	1	4	
CRO	10-Sep-91	Lc	RVERSIDE	294	600	1	2	4
CRO	13-Jun-90	C	HNGEL_CL	294	240	2	2	1
CRO	09-Jan-90	Om	TENBOSCH	293	867	1	3	
CRO	10-Oct-90	Lm	LIONS_CL	293	750	1	5	
CRO	07-Mar-90	Lm	LIONS_CL	221	270	1	2	
CRO	08-Jan-91	Lr	TENBOSCH	300	950	2	5	4
CRO	09-Jan-90	Om	TENBOSCH	292	1400	1	3	2
CRO	12-Jun-90	Tr	RVERSIDE	222	550	1	3	4
CRO	14-Jun-90	Bm	RVULETTS	222	200	1	3	
CRO	13-Jun-90	C	HNGEL_CL	652	3480	2	2	2

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	11-Oct-90	C	CROC_HOT	685	3250	1	4	4
CRO	13-Sep-89	C	HNGEL_CL	292	300	1	2	
CRO	10-Sep-91	Lc	RVERSIDE	290	700	2	2	
CRO	09-Jan-91	Bm	HNGEL_CL	223	220	1	5	3
CRO	09-Jan-91	Bm	HNGEL_CL	223	240	1	2	
CRO	12-Sep-91	Lm	MATAFFIN	223	250	1	1	
CRO	09-Jan-90	Om	TENBOSCH	291	770	2	4	4
CRO	13-Sep-89	C	HNGEL_CL	291	260	2	1	
CRO	09-Oct-90	Si	RVERSIDE	223	210	2	3	2
CRO	12-Jun-90	Lr	RVERSIDE	290	780	2	1	
CRO	13-Jun-89	Om	TENBOSCH	289	920	2	3	
CRO	14-Jun-89	Lm	RVERSIDE	289	620	2	1	
CRO	13-Sep-89	Om	TENBOSCH	223	440	1	2	
CRO	13-Sep-89	Lm	LIONS_CL	290	650	2	4	
CRO	10-Sep-91	Om	TENBOSCH	286	950	2	3	4
CRO	12-Jun-90	Hv	TENBOSCH	286	300	2	1	1
CRO	10-Sep-91	Lc	RVERSIDE	286	650	1	2	4
CRO	10-Sep-91	Om	TENBOSCH	285	850	2	3	7
CRO	13-Sep-89	Om	TENBOSCH	285	660	2	4	
CRO	14-Mar-91	Bm	CROC_HOT	285	550	1	5	
CRO	09-Oct-90	Tr	TENBOSCH	284	1300	1	5	
CRO	09-Oct-90	Si	RVERSIDE	284		2		
CRO	06-Mar-90	Lc	RVERSIDE	284	500	1	1	
CRO	12-Sep-91	Bm	MATAFFIN	284	650	1	5	3
CRO	16-Sep-92	C	MATAFFIN	640	3000	1	3	3
CRO	09-Sep-91	Om	TENBOSCH	282	1010	1	5	5
CRO	09-Oct-90	Lm	RVERSIDE	282	725	2	5	4
CRO	14-Jun-90	Bm	RVULETTS	225	200	1	5	
CRO	12-Mar-91	Om	TENBOSCH	283	930	2	4	
CRO	14-Sep-89	Lm	RVERSIDE	282	598	2	2	
CRO	13-Mar-91	Lr	RVERSIDE	281	620	2	1	
CRO	09-Oct-90	Bm	RVERSIDE	226	300	1	5	
CRO	10-Sep-91	Lc	RVERSIDE	282	520	2	2	
CRO	13-Sep-89	Om	TENBOSCH	280	800	2	6	
CRO	13-Mar-91	Lc	RVERSIDE	280	700	1	2	
CRO	12-Jun-90	Om	RVERSIDE	227	490	2	3	5
CRO	09-Oct-90	Bm	RVERSIDE	227	375	1	1	3
CRO	13-Sep-89	Bm	HNGEL_CL	228	320	1	2	
CRO	13-Sep-89	Bm	HNGEL_CL	228	230	1	3	
CRO	14-Mar-91	Bm	MATAFFIN	281	650	2	2	
CRO	12-Sep-91	Bm	MATAFFIN	284	550	1	6	3
CRO	14-Sep-89	Tr	RVERSIDE	228	590	1	3	
CRO	10-Oct-90	Si	LIONS_CL	285	300	2	3	3
CRO	14-Mar-91	Bm	CROC_HOT	230	255	1	1	
CRO	10-Sep-91	Lm	RVERSIDE	285	570	1	5	3
CRO	10-Sep-91	Om	TENBOSCH	279	940	1	4	
CRO	10-Sep-91	Tr	TENBOSCH	278	1050	1	4	
CRO	09-Jan-90	Om	TENBOSCH	278	740	2	5	4
CRO	13-Mar-91	Lc	RVERSIDE	278	660	1	2	
CRO	13-Jun-90	Lm	HNGEL_CL	278	490	2	2	
CRO	10-Sep-91	Om	TENBOSCH	277	750	2	3	4
CRO	09-Sep-91	Om	TENBOSCH	277	940	1	5	4
CRO	08-Jan-91	Hv	TENBOSCH	277	480	2	5	0
CRO	14-Jun-90	Bm	RVULETTS	277	480	2	4	2
CRO	10-Sep-91	Lm	RVERSIDE	230	250	1	1	3
CRO	10-Sep-91	Lc	RVERSIDE	230	300	1	1	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	12-Jun-90	Om	TENBOSCH	279	900	2	2	
CRO	13-Sep-89	Bm	HNGEL_CL	287	300	1	1	
CRO	09-Jan-91	Bm	HNGEL_CL	277	480	2	5	2
CRO	09-Oct-90	Om	TENBOSCH	276	950	2	4	4
CRO	13-Sep-89	Tr	TENBOSCH	275	880	1	4	
CRO	12-Jun-90	Om	TENBOSCH	275	875	2	3	6
CRO	09-Oct-90	Tr	TENBOSCH	280	1280	1	5	
CRO	07-Mar-90	Lm	LIONS_CL	275	480	2	2	
CRO	09-Oct-90	Tr	TENBOSCH	274	1150	1	4	
CRO	09-Oct-90	Om	TENBOSCH	273	900	1	5	5
CRO	09-Sep-91	Om	TENBOSCH	273	910	1	5	4
CRO	12-Jun-90	Lr	RVERSIDE	273	560	2	1	
CRO	10-Sep-91	Lm	RVERSIDE	232	250	1	1	
CRO	13-Sep-89	C	HNGEL_CL	440	810	1	3	
CRO	09-Oct-90	Lc	RVERSIDE	268	575	1	1	2
CRO	12-Jun-90	Tr	TENBOSCH	267	920	1	4	6
CRO	12-Jun-90	Om	TENBOSCH	232	480	2	2	
CRO	12-Jun-90	Om	TENBOSCH	232	550	2	2	
CRO	12-Jun-90	Om	TENBOSCH	232	320	2	2	4
CRO	09-Oct-90	Lm	RVERSIDE	269	550	2	5	
CRO	08-Jan-91	Hv	TENBOSCH	267	360	2	2	0
CRO	10-Oct-90	Lm	LIONS_CL	267	625	2	4	
CRO	09-Oct-90	Lc	RVERSIDE	233	375	1	3	
CRO	09-Oct-90	Lc	RVERSIDE	233	375	1	2	1
CRO	10-Sep-91	Tr	TENBOSCH	269	1000	1	4	
CRO	13-Mar-91	Lm	LIONS_CL	270	440	2	2	
CRO	12-Jun-90	Om	TENBOSCH	233	500	1	4	
CRO	09-Sep-91	Tr	TENBOSCH	233	810	2	3	
CRO	12-Sep-91	Bm	MATAFFIN	234	270	1	4	2
CRO	10-Sep-91	Bm	RVERSIDE	234	250	1	2	2
CRO	09-Oct-90	Lc	RVERSIDE	234	400	1	4	
CRO	09-Oct-90	Lm	RVERSIDE	270	575	2	5	2
CRO	13-Sep-89	Om	LIONS_CL	235	480	2	4	
CRO	13-Mar-91	Lc	RVERSIDE	270	700	1	2	
CRO	13-Mar-91	Lc	RVERSIDE	266	560	2	1	
CRO	11-Sep-91	Bm	LIONS_CL	266	540	1	6	4
CRO	11-Sep-91	Bm	LIONS_CL	266	500	1	2	4
CRO	09-Oct-90	Tr	TENBOSCH	265	900	2	3	
CRO	09-Oct-90	Lc	RVERSIDE	263	575	1	5	
CRO	12-Jun-90	Om	TENBOSCH	262	800	2	2	4
CRO	09-Jan-90	Tr	TENBOSCH	262	780	2	4	4
CRO	09-Oct-90	Lc	RVERSIDE	262	550	1	2	2
CRO	09-Oct-90	Bm	RVERSIDE	262	500	2	5	
CRO	09-Oct-90	Si	RVERSIDE	260	240	2	2	3
CRO	13-Sep-89	Tr	TENBOSCH	245	680	2	4	
CRO	14-Jun-90	Bm	RVULETTS	245	350	1	3	
CRO	06-Mar-90	Lc	RVERSIDE	257	420	1	4	
CRO	13-Mar-91	Bm	HNGEL_CL	257	450	2	4	
CRO	14-Sep-89	Bm	CROC_HOT	236	350	1	3	
CRO	09-Oct-90	Tr	TENBOSCH	258	1050	1	5	
CRO	09-Jan-91	Bm	HNGEL_CL	236	350	2	6	2
CRO	10-Sep-91	Si	RVERSIDE	259	270	2	3	
CRO	14-Jun-90	Bm	RVULETTS	256	360	1	4	
CRO	09-Oct-90	Si	RVERSIDE	236	230	2	2	2
CRO	09-Oct-90	Si	RVERSIDE	236	240	2	3	3
CRO	09-Oct-90	Bm	RVERSIDE	256	425	2	5	
CRO	09-Oct-90	Si	RVERSIDE	256	260	2	3	3

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	13-Jun-89	Om	TENBOSCH	236	580	1	2	
CRO	11-Sep-91	Bm	LIONS_CL	237	320	1	6	4
CRO	09-Oct-90	Bm	RVERSIDE	237	350	1	5	2
CRO	09-Oct-90	Lc	RVERSIDE	246	450	1	3	
CRO	12-Jun-90	Tr	RVERSIDE	238	700	1	3	4
CRO	09-Oct-90	Bm	RVERSIDE	246	425	1	5	2
CRO	09-Oct-90	Lm	RVERSIDE	256	525	1	5	3
CRO	12-Jun-90	Om	TENBOSCH	239	460	2	2	
CRO	06-Mar-90	Lr	RVERSIDE	260	400	1	4	7
CRO	09-Oct-90	Bm	RVERSIDE	256	475	2	5	2
CRO	13-Sep-89	Tr	TENBOSCH	255	800	2	4	
CRO	07-Mar-90	Lm	LIONS_CL	240	260	1	2	
CRO	10-Oct-90	Lm	LIONS_CL	256	525	1	4	3
CRO	12-Jun-90	Tr	TENBOSCH	255	900	1	4	5
CRO	14-Jun-90	Bm	RVULETTS	255	350	1	5	
CRO	10-Sep-91	Lm	RVERSIDE	240	300	1	2	2
CRO	09-Oct-90	Lc	RVERSIDE	240	425	1	2	
CRO	14-Jun-90	Bm	RVULETTS	240	250	1	3	
CRO	09-Oct-90	Lm	RVERSIDE	260	600	1	5	
CRO	14-Sep-89	Tr	RVERSIDE	246	660	1	5	
CRO	14-Jun-90	Bm	RVULETTS	253	250	2	4	3
CRO	09-Jan-90	Tr	TENBOSCH	251	740	2	5	
CRO	09-Jan-90	Tr	TENBOSCH	240	720	2	5	
CRO	13-Sep-89	Tr	TENBOSCH	240	680	2	3	
CRO	16-Sep-92	Tr	TENBOSCH	230	619	2	2	
CRO	09-Jan-90	Tr	TENBOSCH	241	710	2	4	3
CRO	15-Jun-89	Si	LIONS_CL	252	215	2	2	
CRO	16-Sep-92	Tr	TENBOSCH	265	809	2	2	
CRO	07-Mar-90	Bm	LIONS_CL	242	300	1	5	
CRO	09-Oct-90	Lc	RVERSIDE	242	425	1	1	
CRO	09-Oct-90	Lc	RVERSIDE	242	425	1	3	
CRO	09-Oct-90	Lc	RVERSIDE	242	425	1	2	
CRO	07-Mar-90	Om	LIONS_CL	254	610	1	5	4
CRO	12-Mar-91	Om	TENBOSCH	254	800	1	3	
CRO	09-Oct-90	Lc	RVERSIDE	253	425	1	1	
CRO	13-Jun-90	C	LIONS_CL	794	2350	2	2	
CRO	13-Sep-89	Tr	TENBOSCH	242	780	1	4	
CRO	09-Oct-90	Om	TENBOSCH	242	575	2	4	3
CRO	16-Sep-92	Tr	TENBOSCH	270	1134	1	5	
CRO	13-Mar-91	Lc	RVERSIDE	289	710	1	2	
CRO	09-Oct-90	Lc	RVERSIDE	244	475	1	3	
CRO	10-Sep-91	Tr	TENBOSCH	244	750	2	3	
CRO	15-Jun-89	C	LIONS_CL	695	3900	2	2	
CRO	13-Sep-89	Bm	HNGEL_CL	245	360	1	2	
CRO	09-Oct-90	Lc	RVERSIDE	256	600	1	3	
CRO	10-Sep-91	Lc	RVERSIDE	255	450	2	2	
CRO	06-Mar-90	Tr	TENBOSCH	288	760	2	4	3
CRO	08-Jan-91	Tr	TENBOSCH	276	980	1	4	3
CRO	09-Oct-90	Lc	RVERSIDE	266	625	1	3	
CRO	13-Sep-89	Lm	HNGEL_CL	265	460	1	3	
CRO	13-Mar-91	Lc	RVERSIDE	263	470	1	1	
CRO	12-Jun-90	Tr	TENBOSCH	268	1050	1	4	4
CRO	10-Sep-91	Si	RVERSIDE	245	200	2	2	
CRO	09-Oct-90	Lm	RVERSIDE	245	475	1	5	2
CRO	09-Oct-90	Lc	RVERSIDE	245	475	1	2	
CRO	10-Sep-91	Om	TENBOSCH	265	850	2	4	4

River	Date	spp	Site	Length	Mass	Gender	GI	Age
CRO	10-Sep-91	Tr	TENBOSCH	264	950	1	4	
CRO	12-Jun-90	Om	TENBOSCH	275	820	2	2	7
CRO	10-Sep-91	Si	RVERSIDE	262	250	2	2	
CRO	14-Jun-90	Bm	RVULETTS	272	510	2	4	2
LET	11-May-93	Lr	HUDSON	242	374	2	2	
LET	09-Aug-90	Lr	PUMP	245	300	1	1	2
LET	19-Nov-90	Bm	ENGELHRT	245	250	2	4	3
LET	09-Aug-90	Bm	PUMP	241	320	2	2	
LET	20-Aug-91	Lm	SLAB	240	368	2	2	
LET	20-Nov-90	Om	SLAB	205	200	1	3	1
LET	07-Aug-90	Bm	PRIESKA	208	200	2	1	
LET	07-Aug-90	Lm	SLAB	235	310	2	2	
LET	09-Aug-90	Lr	PUMP	245	370	1	3	2
LET	20-Aug-91	Lm	SLAB	242	401	2	1	
LET	21-May-91	Lm	SLAB	233	180	2	2	2
LET	09-Aug-90	Lr	PUMP	245	280	1	3	
LET	20-Nov-90	Om	SLAB	242	530	1	5	
LET	10-May-90	Bm	PRIESKA	235	300	2	1	
LET	23-May-91	Bm	PUMP	245	400	2	2	4
LET	07-Aug-90	Si	PRIESKA	244	195	2	2	1
LET	09-Aug-90	Bm	PUMP	227	285	2	1	
LET	07-Aug-90	Om	PRIESKA	232	460	1		4
LET	11-May-93	Lr	HUDSON	245	387	2	1	2
LET	20-May-91	Om	PRIESKA	228	240	2	4	
LET	09-Aug-90	Bm	PUMP	230	320	1	4	
LET	23-May-91	Bm	PUMP	245	300	1	5	4
LET	22-Aug-91	Si	PRIESKA	245	218	2	2	4
LET	22-Aug-91	Si	PRIESKA	245	210	2	3	
LET	11-May-93	Lr	HUDSON	243	387	2	2	3
LET	09-Aug-90	Lm	PUMP	240	250	1	3	1
LET	20-May-91	Om	SLAB	242	450	1	3	5
LET	09-Aug-90	Bm	PUMP	251	400	1	3	
LET	09-Aug-90	Tr	PUMP	140	100	1	2	
LET	08-May-90	Lm	SLAB	242	360	1	2	
LET	11-May-93	Lr	HUDSON	242	406	2	2	
LET	19-Nov-90	Si	ENGELHRT	236	190	2	3	2
LET	20-Nov-90	Om	SLAB	235	450	2	2	
LET	20-Feb-90	Om	JUNCTION	252	670	2	5	
LET	20-Feb-90	Om	JUNCTION	252	650	2	5	
LET	19-Feb-90	Lr	PRIESKA	3	400	1	2	
LET	20-Feb-90	Om	JUNCTION	253	700	2	5	
LET	20-Feb-90	Om	JUNCTION	253	750	2	4	
LET	20-Aug-91	Lm	SLAB	240	368	2	1	
LET	20-Aug-91	Lm	SLAB	236	426	2	2	
LET	20-Feb-90	Om	JUNCTION	254	700	2	4	
LET	20-Aug-91	Lm	SLAB	240	400	2	2	
LET	09-Aug-90	Bm	PUMP	254	340	1	6	2
LET	13-Feb-91	Om	JUNCTION	240	520	2	4	5
LET	22-Aug-91	Si	PRIESKA	255	227	2	2	
LET	22-Aug-91	Si	PRIESKA	255	220	2	2	
LET	23-May-91	Om	PUMP	255	600	1	3	5
LET	23-May-91	Om	PUMP	255	600	1	5	4
LET	09-Aug-90	Lm	PUMP	255	290	1	3	
LET	09-Aug-90	Si	PUMP	255	200	2	2	2
LET	20-Aug-91	Lm	SLAB	240	372	2	2	
LET	23-May-91	Om	PUMP	240	600	1	2	
LET	23-May-91	Lm	PUMP	240	250	1	2	3

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	09-Aug-90	Bm	PUMP	238	270	1	3	
LET	20-Feb-90	Om	JUNCTION	256	660	2	4	
LET	22-Feb-90	Om	JUNCTION	239	520	2		4
LET	20-Aug-91	Om	PUMP	256	910	1	3	5
LET	11-May-93	Lr	HUDSON	240	414	2	2	2
LET	19-Nov-90	Om	ENGELHRT	240	250	2	3	1
LET	21-May-91	Lm	SLAB	238	250	2	2	3
LET	20-Feb-90	Bm	SLAB	236	300	1	2	
LET	22-May-91	Om	JUNCTION	246	750	2	2	4
LET	11-May-93	Lr	HUDSON	236	367	1	1	
LET	07-Aug-90	Lm	SLAB	235	290	1	3	
LET	13-Feb-91	Om	JUNCTION	257	700	2	4	4
LET	07-Aug-90	Lm	SLAB	245	300	1	3	
LET	08-May-90	Lm	SLAB	257	435	1	4	
LET	21-May-91	Lm	SLAB	235	280	2	2	2
LET	19-Nov-90	Si	ENGELHRT	246	200	2	3	2
LET	19-Nov-90	Bm	ENGELHRT	260	260	2	5	3
LET	19-Nov-90	Bm	ENGELHRT	260	260	1	5	3
LET	13-Feb-91	Om	JUNCTION	260	750	2	4	4
LET	10-May-90	Lm	PRIESKA	260	340	2	3	
LET	22-Aug-91	Si	PRIESKA	260	277	2	2	4
LET	23-May-91	Lr	PUMP	260	550	2	2	
LET	23-May-91	Om	PUMP	260	900	1	3	
LET	23-May-91	Om	PUMP	260	1000	1	3	
LET	23-May-91	Om	PUMP	260	700	1	3	
LET	23-May-91	Om	PUMP	260	990	1	3	7
LET	09-Aug-90	Si	PUMP	260	240	2	4	4
LET	09-Aug-90	Lr	PUMP	235	220	1	2	
LET	09-Aug-90	Bm	PUMP	201	98	1	2	
LET	19-Feb-90	Om	PRIESKA	203	330	2	4	
LET	20-Aug-91	Mm	JUNCTION	261	221	1	3	
LET	22-Nov-90	Lm	JUNCTION	261	800	2	4	2
LET	20-May-91	Bm	PRIESKA	261	400	1	4	
LET	22-Feb-90	Om	JUNCTION	262	750	1	4	4
LET	08-Aug-90	Om	JUNCTION	262	680	2	5	4
LET	08-Aug-90	Om	JUNCTION	262	740	2	5	4
LET	09-Aug-90	Lr	PUMP	235	320	1	2	1
LET	09-Aug-90	Lr	PUMP	235	280	1	4	
LET	09-Aug-90	Bm	PUMP	235	220	1	1	
LET	23-May-91	Bm	PUMP	235	300	1	3	
LET	21-May-91	Lm	SLAB	232	200	2	2	2
LET	20-Feb-90	Om	JUNCTION	263	780	2	4	
LET	20-Feb-90	Om	JUNCTION	263	740	1	4	
LET	20-Feb-90	Om	JUNCTION	263	870	2	4	
LET	23-May-91	Om	PUMP	235	600	2	2	
LET	07-Aug-90	Om	PRIESKA	233	495	1	4	
LET	20-Feb-90	Om	JUNCTION	264	720	1	4	
LET	19-Feb-90	Lr	PRIESKA	264	520	2	2	
LET	10-May-90	Si	PRIESKA	264	260	2	3	
LET	08-May-90	Lm	SLAB	233	355	1	4	
LET	12-Feb-91	Om	PRIESKA	213	210	2	2	
LET	13-Feb-91	Om	JUNCTION	265	770	2	4	4
LET	10-May-90	Bm	PRIESKA	265	450	1	5	
LET	07-Aug-90	Si	PRIESKA	265	270	2	2	
LET	22-Aug-91	Si	PRIESKA	265	280	2	2	
LET	23-May-91	Om	PUMP	235	600	2	2	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	22-Aug-91	Om	PRIESKA	235	480	2	4	4
LET	22-Aug-91	Si	PRIESKA	235	180	2	2	
LET	10-May-90	Si	PRIESKA	235	200	2	3	
LET	10-May-90	Bm	PRIESKA	266	460	2	3	
LET	08-Aug-90	Om	JUNCTION	235	480	2	2	3
LET	21-May-91	Lm	SLAB	214	220	2	2	3
LET	07-Aug-90	Om	PRIESKA	233	405	1	4	
LET	22-May-91	Om	JUNCTION	233	520	1	2	3
LET	20-May-91	Om	SLAB	232	450	1	4	4
LET	20-Nov-90	Om	SLAB	210	300	1	2	2
LET	21-May-91	Bm	SLAB	268	600	2	5	3
LET	20-May-91	Om	PRIESKA	211	220	1	3	3
LET	13-Feb-91	Om	JUNCTION	269	850	1	2	4
LET	20-Nov-90	Om	SLAB	211	450	1	3	
LET	20-Aug-91	Om	PUMP	212	390	2	3	4
LET	08-Aug-90	Om	JUNCTION	270	850	1	3	4
LET	21-May-91	Lm	SLAB	212	180	1	2	
LET	10-May-90	Bm	PRIESKA	270	420	2	4	
LET	10-May-90	Si	PRIESKA	270	330	2	3	
LET	22-Aug-91	Si	PRIESKA	270	307	2	2	3
LET	22-Aug-91	Si	PRIESKA	270	291	2	3	4
LET	20-May-91	Om	SLAB	232	550	1	4	4
LET	10-May-90	Bm	PRIESKA	214	220	1	3	
LET	08-May-90	Bm	SLAB	270	543	2	2	
LET	21-May-91	Bm	SLAB	270	500	2	4	4
LET	07-Aug-90	Lm	SLAB	270	440	1	3	1
LET	22-Feb-90	Om	JUNCTION	271	780	1		5
LET	10-May-90	Bm	PRIESKA	271	520	2	2	
LET	22-Feb-90	Om	JUNCTION	272	770	1	5	3
LET	20-Feb-90	Om	JUNCTION	272	880	2	5	3
LET	09-Aug-90	Bm	PUMP	272	520	2	5	1
LET	20-May-91	Om	PRIESKA	228	300	2	4	4
LET	12-Feb-91	Lc	PRIESKA	232	210	2	4	
LET	08-Aug-90	Om	JUNCTION	232	570	1	1	3
LET	22-Feb-90	Om	JUNCTION	232	460	2		4
LET	19-Nov-90	Lr	ENGELHRT	232	220	1	1	3
LET	20-Nov-90	Om	SLAB	231	500	1	4	4
LET	22-Aug-91	Si	PRIESKA	275	289	2	3	
LET	23-May-91	Om	PUMP	275	1000	1	4	6
LET	23-May-91	Om	PUMP	275	1000	1	3	5
LET	23-May-91	Bm	PUMP	275	500	1	2	4
LET	23-May-91	Om	PUMP	275	1000	1	4	4
LET	09-Aug-90	Om	PUMP	275	780	1	3	5
LET	09-Aug-90	Si	PUMP	275	340	2	4	3
LET	09-Aug-90	Lm	PUMP	275	320	2	2	1
LET	22-May-91	Om	JUNCTION	231	550	1	2	4
LET	20-Aug-91	Lm	SLAB	230	327	2	1	
LET	20-Aug-91	Lm	SLAB	230	307	2	2	
LET	20-Feb-90	Om	JUNCTION	276	660	1	4	
LET	20-Aug-91	Lm	SLAB	230	366	2	1	
LET	07-Aug-90	Om	SLAB	230	410	1	2	4
LET	07-Aug-90	Om	SLAB	230	300	1	2	4
LET	23-May-91	Om	PUMP	230	600	1	2	
LET	23-May-91	Om	PUMP	230	600	2	2	
LET	23-May-91	Om	PUMP	230	500	2	2	
LET	23-May-91	Lr	PUMP	230	400	1	1	3
LET	22-Aug-91	Si	PRIESKA	230	170	2	2	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	22-Aug-91	Om	PRIESKA	230	470	1	4	4
LET	10-May-90	Om	PRIESKA	230	390	2	2	
LET	20-Aug-91	Om	SLAB	228	411	2	4	3
LET	22-Feb-90	Om	JUNCTION	279	795	1	5	4
LET	10-May-90	Bm	PRIESKA	230	300	1	3	
LET	11-May-93	Lr	HUDSON	230	355	2	2	
LET	22-May-91	Lm	JUNCTION	227	250	1	3	3
LET	23-May-91	Om	PUMP	225	500	2	2	
LET	19-Feb-90	Lr	PRIESKA	226	400	1	2	
LET	11-May-93	Om	HUDSON	281	842	2	4	2
LET	22-Nov-90	Om	JUNCTION	281	1200	1	4	
LET	20-May-91	Om	SLAB	226	400	1	2	4
LET	09-Aug-90	Bm	PUMP	225	240	1	2	
LET	13-Feb-91	Om	JUNCTION	282	900	1	3	4
LET	07-Aug-90	Om	SLAB	225	460	1	3	3
LET	20-May-91	Om	SLAB	225	280	2	2	3
LET	09-Aug-90	Lr	PUMP	225	260	1	1	2
LET	21-May-91	Lr	SLAB	282	600	1	2	
LET	09-Aug-90	Bm	PUMP	215	210	1	1	
LET	20-Nov-90	Lm	SLAB	215	250	2	5	1
LET	20-Feb-90	Om	JUNCTION	284	750	2	4	
LET	20-Feb-90	Om	JUNCTION	284	760	2	4	
LET	23-May-91	Lm	PUMP	225	250	2	2	2
LET	23-May-91	Om	PUMP	225	400	2	2	
LET	23-May-91	Lm	PUMP	225	300	2	2	3
LET	23-May-91	Bm	PUMP	225	300	2	2	
LET	23-May-91	Om	PUMP	225	700	2	2	5
LET	09-Aug-90	Bm	PUMP	220	230	1	2	
LET	09-Aug-90	Bm	PUMP	220	250	1	4	
LET	10-May-90	Bm	PRIESKA	285	440	2	1	
LET	23-May-91	Om	PUMP	285	1100	1	4	
LET	23-May-91	Lr	PUMP	225	400	2	2	
LET	23-May-91	Om	PUMP	225	500	2	2	
LET	22-Aug-91	Om	PRIESKA	225	325	1	3	4
LET	11-May-93	Lr	HUDSON	225	320	2	2	2
LET	21-May-91	Lm	SLAB	224	250	2	2	2
LET	20-Aug-91	Om	SLAB	220	406	2	4	4
LET	19-Nov-90	Lr	ENGELHRT	223	218	2	4	3
LET	22-Nov-90	Om	JUNCTION	287	1250	1	5	
LET	20-Feb-90	Om	JUNCTION	288	720	2	5	
LET	20-Nov-90	Om	SLAB	223	300	1	2	4
LET	20-Aug-91	Om	JUNCTION	289	753	1	4	4
LET	11-May-93	Lr	HUDSON	224	305	2	2	
LET	20-Nov-90	Om	SLAB	223	500	1	3	
LET	20-May-91	Om	PRIESKA	223	350	2	2	4
LET	11-May-93	Om	HUDSON	290	859	2	2	3
LET	20-Nov-90	Om	SLAB	223	300	2	5	4
LET	22-Aug-91	C	PRIESKA	290	316	2	2	
LET	09-Aug-90	C	PUMP	290	280	1	2	
LET	20-May-91	Om	PRIESKA	223	230	1	3	
LET	07-Aug-90	Om	PRIESKA	222	445	1	4	1
LET	07-Aug-90	Lm	SLAB	290	540	2	3	1
LET	20-Feb-90	Bm	SLAB	222	280	1	2	
LET	07-Aug-90	Si	PRIESKA	291	360	2	3	3
LET	20-Nov-90	Om	SLAB	222	300	1	3	4
LET	21-May-91	Lm	SLAB	222	200	2	2	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	20-Feb-90	Bm	SLAB	221	250	1	2	
LET	07-Aug-90	Lm	SLAB	220	220	1	3	1
LET	20-May-91	Om	SLAB	220	350	2	2	4
LET	21-May-91	Lm	SLAB	220	210	1	3	
LET	20-May-91	Om	SLAB	220	380	1	3	4
LET	20-May-91	Om	SLAB	220	380	2	2	4
LET	09-Aug-90	Lr	PUMP	220	190	1	4	
LET	22-Aug-91	Si	PRIESKA	295	366	2	4	
LET	23-May-91	Lr	PUMP	220	300	2	2	
LET	23-May-91	Om	PUMP	220	500	2	2	
LET	23-May-91	Lr	PUMP	220	300	1	2	
LET	23-May-91	Om	PUMP	220	500	2	2	4
LET	23-May-91	Lr	PUMP	220	350	1	1	3
LET	23-May-91	Lr	PUMP	220	400	2	2	
LET	23-May-91	Om	PUMP	220	500	2	2	
LET	23-May-91	Om	PUMP	220	400	2	2	
LET	21-May-91	Lm	SLAB	218	220	2	2	3
LET	11-May-93	Lr	HUDSON	220	256	2	2	
LET	22-Aug-91	Si	PRIESKA	300	587	2	3	
LET	09-Aug-90	Si	PUMP	300	420	2	2	1
LET	23-May-91	Om	PUMP	220	500	2	2	4
LET	22-Aug-91	Om	PRIESKA	220	360	1	3	4
LET	07-Aug-90	Om	PRIESKA	220	440	1	3	2
LET	22-Aug-91	Om	PRIESKA	220	430	1	3	3
LET	11-May-93	Lr	HUDSON	220	289	2	1	2
LET	11-May-93	Lr	HUDSON	220	256	2	2	
LET	22-Feb-90	Om	JUNCTION	218	445	2	6	3
LET	11-May-93	Lr	HUDSON	218	271	2	2	
LET	19-Nov-90	Si	ENGELHRT	218	180	2	3	2
LET	21-May-91	Lm	SLAB	216	180	2	2	
LET	21-May-91	Lm	SLAB	216	210	2	2	
LET	07-Aug-90	Om	PRIESKA	216	400	1	4	2
LET	20-Aug-91	Lr	JUNCTION	216	230	1	1	
LET	07-Aug-90	C	SLAB	215	320	1	2	
LET	23-May-91	Lr	PUMP	215	250	2	2	
LET	23-May-91	Om	PUMP	215	450	1	1	
LET	23-May-91	Om	PUMP	215	500	2	2	
LET	23-May-91	Bm	PUMP	215	200	1	2	3
LET	23-May-91	Om	PUMP	215	550	2	2	
LET	23-May-91	Lr	PUMP	215	250	1	2	
LET	23-May-91	Bm	PUMP	215	250	1	2	3
LET	23-May-91	Bm	PUMP	215	250	1	2	3
LET	10-May-90	Om	PRIESKA	215	350	1	4	4
LET	20-Feb-90	Om	JUNCTION	213	460	2	4	2
LET	11-May-93	Lr	HUDSON	213	259	1	1	
LET	21-May-91	Lm	SLAB	212	210	2	3	
LET	20-May-91	Om	PRIESKA	212	350	1	3	4
LET	20-Feb-90	Om	JUNCTION	212	420	2	4	
LET	11-May-93	Lr	HUDSON	212	255	1	1	
LET	20-Aug-91	Om	PUMP	209	560	1	2	4
LET	10-May-90	Bm	PRIESKA	320	740	1	4	
LET	20-Nov-90	Om	SLAB	210	300	1	2	
LET	20-Nov-90	Om	SLAB	209	500	1	3	
LET	12-Feb-91	C	PRIESKA	322	400	2	1	
LET	07-Aug-90	Lm	SLAB	210	205	1	3	1
LET	07-Aug-90	Om	SLAB	210	295	2	2	3
LET	07-Aug-90	Lm	SLAB	210	200	1	3	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	09-Aug-90	Om	PUMP	210	340	1	1	3
LET	23-May-91	Lr	PUMP	210	300	2	2	
LET	23-May-91	Bm	PUMP	210	250	1	2	
LET	23-May-91	Lr	PUMP	210	250	2	2	
LET	23-May-91	Om	PUMP	210	500	2	2	
LET	23-May-91	Om	PUMP	210	400	2	2	
LET	22-Aug-91	C	PRIESKA	330	540	1	1	
LET	23-May-91	Lr	PUMP	210	300	2	2	
LET	23-May-91	Om	PUMP	210	500	2	2	
LET	20-Feb-90	Si	SLAB	330	560	2	4	
LET	23-May-91	Lr	PUMP	210	300	2	2	
LET	23-May-91	Lr	PUMP	210	400	2	2	
LET	22-Aug-91	Om	PRIESKA	210	400	1	3	4
LET	12-Feb-91	Lr	PRIESKA	210	200	1	1	1
LET	11-May-93	Om	HUDSON	210	325	2	2	1
LET	12-Feb-91	Lm	SLAB	209	190	2	5	
LET	20-Feb-90	Bm	SLAB	208	280	1	2	
LET	08-May-90	Lm	SLAB	207	217	1	4	
LET	20-May-91	Om	PRIESKA	206	230	2	3	4
LET	21-May-91	Bm	SLAB	342	1000	1	3	
LET	22-May-91	Om	JUNCTION	207	450	2	2	3
LET	19-Nov-90	Om	ENGELHRT	206	200	1	1	
LET	23-May-91	Bm	PUMP	205	200	2	2	3
LET	23-May-91	Lr	PUMP	345	1250	2	6	5
LET	20-Aug-91	Lm	SLAB	205	232	2	2	
LET	23-May-91	Lr	PUMP	205	250	2	2	
LET	23-May-91	Om	PUMP	205	400	2	2	
LET	23-May-91	Lr	PUMP	205	300	2	2	3
LET	20-Aug-91	Lr	JUNCTION	204	211	2	2	
LET	07-Aug-90	C	SLAB	350	560	2	4	6
LET	23-May-91	Lr	PUMP	205	200	2	1	
LET	23-May-91	Om	PUMP	205	400	2	2	
LET	23-May-91	Lr	PUMP	205	300	1	1	3
LET	22-Aug-91	Om	PRIESKA	205	360	1	2	4
LET	10-May-90	Bm	PRIESKA	205	210	1	1	
LET	10-May-90	Om	PRIESKA	205	320	1	4	
LET	20-May-91	Om	SLAB	204	260	2	2	
LET	09-Aug-90	Bm	PUMP	204	180	1	2	2
LET	22-Aug-91	C	PRIESKA	360	620	2	1	
LET	22-Feb-90	Om	JUNCTION	204	378	2	2	
LET	19-Nov-90	Om	ENGELHRT	203	240	1	4	
LET	21-May-91	Lm	SLAB	202	190	2	2	
LET	20-May-91	Om	SLAB	202	280	2	2	
LET	21-May-91	Lm	SLAB	202	180	1	2	3
LET	08-May-90	Lm	SLAB	202	198	1	2	
LET	19-Feb-90	Lr	PRIESKA	202	170	1	1	
LET	22-Nov-90	Om	JUNCTION	202	200	2	2	
LET	11-May-93	Lr	HUDSON	202	207	2	1	
LET	11-May-93	Lr	HUDSON	202	225	1	1	
LET	19-Nov-90	Om	ENGELHRT	202	220	2	3	1
LET	11-May-93	C	HUDSON	370	545	2	1	2
LET	19-Nov-90	Om	ENGELHRT	202	220	1	5	
LET	12-Feb-91	C	SLAB	371	600	2	2	
LET	20-Aug-91	Om	JUNCTION	201	335	2	2	4
LET	20-Feb-90	Om	SLAB	200	300	2	5	
LET	07-Aug-90	C	SLAB	375	660	2	1	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	20-Nov-90	Om	SLAB	200	250	1	2	
LET	20-Nov-90	Om	SLAB	200	300	2	3	
LET	20-Aug-91	Lm	SLAB	200	207	2	2	
LET	21-May-91	Lm	SLAB	200	170	2	2	
LET	20-Feb-90	Bm	SLAB	200	200	1	2	
LET	20-Aug-91	Mm	JUNCTION	248	218	1	3	
LET	22-Aug-91	C	PRIESKA	380	729	1	2	
LET	22-Aug-91	C	PRIESKA	380	635	1	2	
LET	09-Aug-90	Sz	PUMP	200	230			
LET	09-Aug-90	Om	PUMP	200	270	1	1	2
LET	23-May-91	Lr	PUMP	200	250	2	1	
LET	20-May-91	C	PRIESKA	381	650	2	1	
LET	23-May-91	Om	PUMP	200	300	2	2	
LET	22-Feb-90	C	JUNCTION	388	565	1	2	
LET	11-May-93	Om	HUDSON	200	290	1	1	1
LET	20-Feb-90	C	SLAB	389	860	1	4	
LET	22-Aug-91	Om	PRIESKA	200	320	2	2	
LET	22-Aug-91	Om	PRIESKA	200	360	1	3	
LET	10-May-90	Om	PRIESKA	200	300	1	3	4
LET	10-May-90	Bm	PRIESKA	200	180	1	3	
LET	10-May-90	Om	PRIESKA	200	320	1	1	
LET	20-Aug-91	C	PUMP	392	700	1	2	
LET	11-May-93	Lr	HUDSON	200	222	1	1	
LET	21-May-91	Lm	SLAB	197	170	2	2	
LET	22-Feb-90	C	JUNCTION	398	650	1	2	
LET	12-Feb-91	Lr	PRIESKA	199	180	2	2	
LET	19-Nov-90	Om	ENGELHRT	199	220	1	2	
LET	08-May-90	Lm	SLAB	198	217	1	3	
LET	21-May-91	Lm	SLAB	198	170	2	2	
LET	12-Feb-91	Om	SLAB	196	320	2	2	1
LET	22-Aug-91	C	PRIESKA	410	600	1	2	
LET	21-May-91	Lm	SLAB	197	175	1	2	
LET	19-Nov-90	Om	ENGELHRT	197	200	1	2	
LET	07-Aug-90	C	SLAB	196	300	2	2	
LET	08-May-90	Om	SLAB	196	276	2	2	
LET	21-May-91	Lm	SLAB	196	180	2	2	
LET	20-Aug-91	C	PUMP	415	760	1	3	
LET	11-May-93	Lr	HUDSON	196	192	1	1	
LET	20-Nov-90	Om	SLAB	195	300	1	2	
LET	21-May-91	Lm	SLAB	195	180	1	2	
LET	23-May-91	Lr	PUMP	195	200	1	1	
LET	09-Aug-90	Sz	PUMP	195	170			
LET	22-Aug-91	C	PRIESKA	420	984	1	2	3
LET	09-Aug-90	Om	PUMP	190	240	1	1	2
LET	23-May-91	Lr	PUMP	195	250	2	2	
LET	23-May-91	Lr	PUMP	195	200	1	1	
LET	22-Feb-90	C	JUNCTION	422	740	1	2	
LET	23-May-91	Lr	PUMP	195	200	2	2	
LET	23-May-91	Lr	PUMP	195	250	2	2	
LET	23-May-91	Om	PUMP	195	400	1	1	4
LET	22-Aug-91	Om	PRIESKA	195	320	2	2	
LET	22-Aug-91	Om	PRIESKA	185	255	2	2	
LET	10-May-90	C	PRIESKA	427	910	2	4	
LET	10-May-90	C	PRIESKA	430	860	1	2	
LET	10-May-90	C	PRIESKA	430	910	1	1	
LET	22-Aug-91	Om	PRIESKA	195	320	2	3	
LET	10-May-90	Bm	PRIESKA	195	190	1	2	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	10-May-90	Om	PRIESKA	195	300	2	3	2
LET	21-May-91	Lm	SLAB	194	170	1	2	
LET	20-Nov-90	Om	SLAB	193	250	1	2	
LET	21-May-91	C	SLAB	438	1200	2	4	
LET	09-Aug-90	Bm	PUMP	194	155	1	2	1
LET	07-Aug-90	Bm	PRIESKA	192	175	2	1	1
LET	19-Feb-90	C	PRIESKA	442	1030	1	2	
LET	22-Aug-91	Om	PRIESKA	193	325	1	3	
LET	20-Aug-91	Om	SLAB	192	343	1	3	3
LET	12-Feb-91	Lm	SLAB	192	180	1	3	
LET	12-Feb-91	Om	SLAB	191	300	2	2	3
LET	12-Feb-91	Om	PRIESKA	181	150	2	1	
LET	23-May-91	Lr	PUMP	190	200	2	1	
LET	22-Aug-91	Om	PRIESKA	190	240	2	3	
LET	22-Aug-91	Om	PRIESKA	190	245	2	3	
LET	10-May-90	Om	PRIESKA	190	270	2	2	2
LET	12-May-93	Bm	MIDLET	190	205	2	1	3
LET	19-Nov-90	Om	ENGELHRT	190	200	2	4	
LET	13-Feb-91	Om	PUMP	189	200	2	2	3
LET	19-Nov-90	Om	ENGELHRT	189	209	2	3	
LET	20-Aug-91	Om	DRIFT	189	240	1		4
LET	20-Nov-90	Om	SLAB	188	150	1	2	
LET	21-May-91	Lm	SLAB	187	160	1	2	
LET	09-Aug-90	Bm	PUMP	185	220	1	2	
LET	23-May-91	Sz	PUMP	185	250			
LET	13-Feb-91	Om	PUMP	185	220	1	2	2
LET	22-Aug-91	Om	PRIESKA	185	310	1	3	
LET	09-Aug-90	C	PUMP	462	1165	1	3	3
LET	09-Aug-90	Sz	PUMP	180	120			
LET	20-Feb-90	C	SLAB	463	1320	1	4	
LET	07-Aug-90	C	PRIESKA	465	1200	2	2	2
LET	12-Feb-91	C	SLAB	465	1500	1	3	
LET	22-Aug-91	Om	PRIESKA	185	250	2	3	
LET	22-Aug-91	Om	PRIESKA	185	300	2	2	
LET	20-Nov-90	Om	SLAB	184	250	2	5	
LET	19-Nov-90	Om	ENGELHRT	184	200	2	1	
LET	12-Feb-91	Om	SLAB	183	300	2	6	1
LET	19-Nov-90	Om	ENGELHRT	183	210	1	1	
LET	12-Feb-91	Om	SLAB	182	250	2	2	2
LET	22-Aug-91	Om	PRIESKA	182	240	2	2	
LET	22-Aug-91	Om	PRIESKA	182	240	2	2	
LET	22-Aug-91	Om	PRIESKA	182	242	2	2	
LET	22-Aug-91	Om	PRIESKA	182	245	1	2	
LET	22-Aug-91	Om	PRIESKA	182	235	1	2	
LET	12-Feb-91	Om	PRIESKA	182	200	1	1	
LET	12-Feb-91	Om	PRIESKA	182	180	2	2	1
LET	13-Feb-91	Om	JUNCTION	182	140	2	1	2
LET	12-Feb-91	Om	PRIESKA	181	180	1	2	
LET	09-Aug-90	Sz	PUMP	180	100	1	3	
LET	20-Aug-91	Om	PUMP	180	260	2	1	3
LET	09-Aug-90	Sz	PUMP	180	100	2	3	2
LET	22-Aug-91	Om	PRIESKA	180	240	2	2	
LET	12-Feb-91	Om	PRIESKA	178	180	1	1	
LET	12-May-93	C	MIDLET	483	1200	1	2	4
LET	22-Aug-91	Om	PRIESKA	180	225	1	2	
LET	22-Aug-91	Om	PRIESKA	180	230	2	2	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	10-May-90	Om	PRIESKA	180	230	2	2	2
LET	12-Feb-91	Om	PRIESKA	180	175	2	2	
LET	12-May-93	Lrd	MIDLET	180	117	2	2	
LET	22-Feb-90	Om	JUNCTION	180	250	1	2	3
LET	19-Nov-90	Om	ENGELHRT	179	190	2	2	
LET	22-Feb-90	Om	JUNCTION	178	225	1	1	2
LET	20-Aug-91	Bm	DRIFT	178	135	2		
LET	09-Aug-90	C	PUMP	498	1505	2	2	6
LET	12-Feb-91	Om	PRIESKA	137	90	1	2	
LET	20-Aug-91	Om	PUMP	176	225	2	2	
LET	22-Feb-90	Om	JUNCTION	176	200	1	1	
LET	20-Aug-91	Om	SLAB	175	235	1	3	4
LET	22-Aug-91	C	PRIESKA	505	1760	2	2	3
LET	22-Feb-90	Om	JUNCTION	176	195	1	1	
LET	07-Aug-90	C	SLAB	175	190	2	2	2
LET	20-Aug-91	C	SLAB	508	1825	1	4	4
LET	20-Aug-91	Om	SLAB	175	239	1	3	4
LET	08-Aug-90	Om	JUNCTION	250	680	2	2	4
LET	10-May-90	C	PRIESKA	510	1580	1	1	
LET	22-Aug-91	Om	PRIESKA	175	205	1	2	
LET	22-Aug-91	Om	PRIESKA	175	210	2	2	
LET	10-May-90	Om	PRIESKA	175	190	1	2	1
LET	12-Feb-91	Om	PRIESKA	175	175	2	2	
LET	11-May-93	Lrd	HUDSON	174	97	2	2	
LET	12-Feb-91	Om	PRIESKA	173	150	1	2	1
LET	12-Feb-91	Om	PRIESKA	172	155	1	2	1
LET	12-Feb-91	Om	PRIESKA	172	105	1	1	
LET	12-Feb-91	Om	PRIESKA	172	110	1	4	1
LET	10-May-90	Si	PRIESKA	250	240	2	3	
LET	23-May-91	Si	PUMP	250	200	2	3	5
LET	21-May-91	Bm	SLAB	524	1900	1	4	
LET	22-Nov-90	Om	JUNCTION	138	200	1	1	
LET	12-May-93	Lrd	MIDLET	172	101	2	1	1.5
LET	22-Feb-90	Om	JUNCTION	172	208	1		3
LET	22-Feb-90	Om	JUNCTION	172	192	1	1	3
LET	12-May-93	Lrd	MIDLET	171	104	2	1	
LET	22-Feb-90	Om	JUNCTION	171	200	2	2	2
LET	21-Nov-90	Lm	PRIESKA	170	253	2	5	3
LET	23-May-91	Si	PUMP	250	200	2	3	6
LET	22-Aug-91	C	PRIESKA	530	2150	2	3	4
LET	22-Aug-91	Om	PRIESKA	170	200	2	3	
LET	22-Aug-91	Om	PRIESKA	170	190	2	2	
LET	27-Aug-91	Om	PRIESKA	170	195	2	2	
LET	12-Feb-91	Om	PRIESKA	170	150	2	2	1
LET	11-May-93	Cc	HUDSON	170	150	-1	-1	
LET	11-May-93	Om	HUDSON	170	199	2	1	1
LET	11-May-93	Om	HUDSON	170	186	1	1	
LET	23-May-91	Om	PUMP	250	800	1	3	5
LET	10-May-90	C	PRIESKA	535	1980	2	2	
LET	12-May-93	Lrd	MIDLET	169	102	2	1	
LET	12-May-93	Om	MIDLET	168	154	2	2	1
LET	20-Aug-91	Bm	DRIFT	167	97	1		
LET	12-Feb-91	Om	PRIESKA	166	170	1	4	
LET	09-Aug-90	Lm	PUMP	250	260	2	2	1
LET	07-Aug-90	C	PRIESKA	550	2100	1	4	4
LET	27-Aug-91	Om	PRIESKA	165	175	1	2	
LET	12-May-93	Lrd	MIDLET	164	94	2	1	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	11-May-93	Lrd	HUDSON	164	67	1	1	
LET	11-May-93	Lrd	HUDSON	164	83	2	2	
LET	12-Feb-91	Om	PRIESKA	163	110	2	2	
LET	11-May-93	Lrd	HUDSON	163	80	2	2	
LET	20-Aug-91	Om	PUMP	162	250	2	1	4
LET	12-May-93	Om	MIDLET	162	153	1	2	
LET	11-May-93	Lrd	HUDSON	162	72	2	1	
LET	20-Feb-90	Om	SLAB	161	160	1	1	
LET	09-Aug-90	Sz	PUMP	160	90	1	4	1
LET	09-Aug-90	Sz	PUMP	160	100			
LET	12-May-93	Lrd	MIDLET	157	89	2	1	1.5
LET	07-Aug-90	C	PRIESKA	580	1960	1	4	4
LET	20-May-91	Om	PRIESKA	160	140	2	2	
LET	12-May-93	Om	MIDLET	160	158	1	2	
LET	11-May-93	Lrd	HUDSON	160	68	2	3	
LET	20-Feb-90	Om	SLAB	159	130	1	2	
LET	27-Aug-91	Om	PRIESKA	158	150	2	2	
LET	27-Aug-91	Om	PRIESKA	158	145	1	2	
LET	20-May-91	Om	PRIESKA	158	130	2	2	
LET	20-May-91	Om	PRIESKA	158	140	1	2	
LET	11-May-93	Lrd	HUDSON	158	78	2	1	
LET	12-May-93	Lrd	MIDLET	157	79	2	2	1
LET	22-Aug-91	C	PRIESKA	610	3000	1	3	5
LET	20-Aug-91	C	SLAB	610	2720	1	2	7
LET	07-Aug-90	C	PRIESKA	614	2650	1	4	3
LET	20-Aug-91	Bm	DRIFT	157	100	1		
LET	20-Feb-90	Om	JUNCTION	155	170	2	3	
LET	22-Aug-91	C	PRIESKA	620	3500	1	5	5
LET	12-Feb-91	Om	PRIESKA	156	120	1	1	
LET	20-Aug-91	Om	SLAB	155	149	2	2	
LET	27-Aug-91	Om	PRIESKA	155	142	1	2	
LET	27-Aug-91	Om	PRIESKA	155	135	2	2	
LET	27-Aug-91	Om	PRIESKA	155	125	1	2	
LET	12-May-93	Lrd	MIDLET	155	83	2	1	
LET	08-Aug-90	C	JUNCTION	628	2800	1	2	4
LET	11-May-93	Lrd	HUDSON	154	72	2	2	
LET	11-May-93	Lrd	HUDSON	154	67	2	2	
LET	11-May-93	Om	HUDSON	154	137	1	1	
LET	20-Aug-91	Om	SLAB	250	691	1	4	5
LET	12-May-93	C	MIDLET	650	6250	1	2	4
LET	11-May-93	Om	HUDSON	154	128	1	1	
LET	12-Feb-91	Om	PRIESKA	152	100	2	2	
LET	20-Aug-91	Om	SLAB	150	126	1	2	
LET	07-Aug-90	Lm	SLAB	250	300	2	3	
LET	12-May-93	C	MIDLET	660	6250	1	2	5
LET	09-Aug-90	Sz	PUMP	150	90			
LET	07-Aug-90	Lm	SLAB	250	370	2	2	
LET	07-Aug-90	Om	PRIESKA	142	95	1	2	
LET	10-May-90	C	PRIESKA	705	4300	1	5	
LET	20-Aug-91	C	ENGELHRT	764	6250	1	5	6
LET	21-Nov-90	Lm	PRIESKA	150	225	2	5	3
LET	27-Aug-91	Om	PRIESKA	150	120	2	1	
LET	12-Feb-91	Om	PRIESKA	150	120	1	3	
LET	11-May-93	Lrd	HUDSON	150	63	2	2	
LET	27-Aug-91	Om	PRIESKA	148	115	1	2	
LET	07-Aug-90	C	SLAB	146	120	1	1	2

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	12-May-93	Lrd	MIDLET	145	69	2	1	
LET	19-Feb-90	Om	PRIESKA	144	110	1	2	
LET	12-May-93	Om	MIDLET	143	101	2	1	2
LET	20-Aug-91	Bm	DRIFT	143	62	2		
LET	11-Jun-92	Lrd	PUMP	162	89	1	1	
LET	12-May-93	Om	MIDLET	142	110	2	2	
LET	20-Aug-91	Lr	JUNCTION	251	390	2	2	
LET	11-Jun-92	Si	PUMP	165	61	-1	-1	2
LET	11-Jun-92	Lr	PUMP	165	116	1	1	
LET	11-Jun-92	Lrd	PUMP	165	86	2	1	
LET	11-Jun-92	Si	PUMP	165	56	2	1	
LET	11-Jun-92	Lrd	PUMP	167	88	1	1	
LET	20-Aug-91	Bm	DRIFT	141	69	-1	-1	
LET	11-Jun-92	Si	PUMP	170	68	1	1	2
LET	11-Jun-92	Lr	PUMP	170	127	1	1	
LET	11-Jun-92	Lrd	PUMP	170	100	1	1	
LET	12-May-93	Lrd	MIDLET	140	61	2	1	
LET	11-Jun-92	Lrd	PUMP	173	105	-1	-1	
LET	11-Jun-92	Lrd	PUMP	175	106	-1	-1	
LET	12-May-93	Om	MIDLET	140	95	1	1	1
LET	10-Jun-92	Si	PRIESKA	244	193	2	2	2
LET	11-Jun-92	Lrd	PUMP	177	107	-1	-1	
LET	11-Jun-92	Lrd	PUMP	177	107	1	1	
LET	21-Nov-90	Lm	PRIESKA	120	225	2	5	2
LET	11-Jun-92	Si	PUMP	180	73	1	1	2
LET	11-Jun-92	Sz	PUMP					
LET	10-Jun-92	Om	JUNCTION	294	782	1	3	
LET	11-Jun-92	Si	PUMP	182	86	1	2	2
LET	10-Jun-92	C	PRIESKA	383	640	1	2	2
LET	10-Jun-92	Om	JUNCTION	291	910	1	3	
LET	12-May-93	Om	MIDLET	127	75	1	1	1
LET	11-Jun-92	Lrd	PUMP	186	132	-1	-1	
LET	10-Jun-92	Om	JUNCTION	290	958	1	3	4
LET	09-Jun-92	C	SLAB	343	556	2	1	2
LET	12-May-93	Om	MIDLET	120	66	2	1	
LET	12-May-93	Om	MIDLET	115	57	2	1	
LET	12-Feb-91	Om	PRIESKA	130	90	1	1	
LET	09-Jun-92	Om	SLAB	195	329	1	2	2
LET	10-Jun-92	Om	JUNCTION	287	878	1	4	3
LET	12-May-93	Om	MIDLET	128	68	1	1	
LET	19-Nov-90	Om	ENGELHRT	108	180	1	1	
LET	12-Feb-91	Om	PRIESKA	137	100	1	1	
LET	11-Jun-92	Lrd	PUMP	200	148	1	2	
LET	10-Jun-92	Lr	JUNCTION	427	261	1	1	
LET	10-Jun-92	Si	JUNCTION	282	277	2	2	
LET	11-Jun-92	Mm	PUMP					
LET	09-Jun-92	Si	CAMP16	276	329	2	3	4
LET	11-Jun-92	Lr	PUMP	275	648	2	1	4
LET	10-Jun-92	C	PRIESKA	720	4000	1	5	2
LET	12-May-93	Om	MIDLET	123	72	2	1	
LET	12-May-93	Om	MIDLET	140	103	2	2	
LET	10-Jun-92	C	PRIESKA	452	1100	2	3	2
LET	22-May-91	Om	JUNCTION	137	130	1	1	3
LET	10-Jun-92	Om	PRIESKA	210	367	2	2	3
LET	10-Jun-92	Si	PRIESKA	226	158	2	2	2
LET	10-Jun-92	Om	PRIESKA	211	364	2	3	2
LET	10-Jun-92	Si	PRIESKA	212	147	2	2	2

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LET	10-Jun-92	C	JUNCTION	638	2500	1	4	3
LET	09-Jun-92	Om	SLAB	214	383	2	2	2
LET	11-Jun-92	Lm	PUMP					
LET	20-Aug-91	Bm	DRIFT	136	58	2	2	
LET	12-May-93	Om	MIDLET	126	63	1	1	1
LET	09-Jun-92	Om	SLAB	216	404	2	3	2
LET	10-Jun-92	Tr	JUNCTION	218	400	1	1	
LET	20-May-91	Om	SLAB	134	110	1	2	
LET	10-Jun-92	Lr	JUNCTION	601	290	2	1	4
LET	20-May-91	Om	SLAB	134	110	2	2	
LET	07-Aug-90	Om	PRIESKA	134	80	2	2	
LET	08-Aug-90	C	JUNCTION		1430	1	1	
LET	10-Jun-92	Om	PRIESKA	221	450	2	4	4
LET	10-Jun-92	Om	PRIESKA	222	434	2	3	4
LET	10-Jun-92	Om	PRIESKA	222	477	1	3	3
LET	10-Jun-92	C	PRIESKA					
LET	10-Jun-92	Si	JUNCTION	230	158	2	2	
LET	09-Jun-92	Lr	CAMP16	230	308	1	1	4
LET	10-Jun-92	Lr	JUNCTION	564	288	2	1	5
LET	09-Jun-92	Lr	CAMP16	223	303	1	1	5
LET	10-Jun-92	Si	PRIESKA	223	182	2	2	2
LET	12-Feb-91	Om	PRIESKA	130	70	1	3	
LET	11-Jun-92	Lr	PUMP	260	417	2	1	4
LET	10-Jun-92	Si	PRIESKA	256	206	2	1	2
LET	10-Jun-92	Om	JUNCTION	225	504	2	2	
LET	10-Jun-92	C	PRIESKA	510	1600	1	3	2
LET	12-Feb-91	Om	PRIESKA	133	90	1	1	
LET	10-Jun-92	Om	JUNCTION	255	594	1	2	4
LET	12-Feb-91	Om	PRIESKA	133	100	1	1	
LET	09-Jun-92	Lr	CAMP16	255	416	1	1	3
LET	11-May-93	Cc	HUDSON	134	81	-1	-1	
LET	12-May-93	Om	MIDLET	126	72	2	1	
LET	10-Jun-92	Om	PRIESKA					
LET	10-Jun-92	Si	PRIESKA	240	176	2	2	2
LET	10-Jun-92	Om	JUNCTION	250	517	2	2	4
LET	11-Jun-92	Lr	PUMP	235	363	2	1	
LET	10-Jun-92	Om	JUNCTION	242	506	2	2	
LET	11-Jun-92	Lr	PUMP	300	827	2	1	4
LET	12-Feb-91	Om	PRIESKA	134	110	1	1	
LET	09-Jun-92	Lr	CAMP16	240	381	1	1	3
LET	09-Jun-92	Lr	CAMP16	238	348	1	1	4
LET	10-Jun-92	C	PRIESKA	500	1200	1	3	1
LEV	21-Jul-93	Om	SETTLMNT	210	365	1	3	
LEV	18-Aug-92	Lr	MKYADNST	320	953	2	1	
LEV	18-Aug-92	Om	SETTLMNT	175	242	1	2	
LEV	18-Aug-92	Lc	MKYADNST	312	1061	2	1	
LEV	18-Aug-92	Lc	MKYADNST	325	1114	2	2	
LEV	22-Jul-93	C	MKYAUPST	550	1670	1	1	3
LEV	18-Aug-92	Lr	MKYADNST	320	1196	2	1	
LEV	21-Jul-93	Om	SETTLMNT	180	235			
LEV	22-Jul-93	C	MKYAUPST	485	1165	1	2	4
LEV	21-Jul-93	Bm	FARM	320	727	2	2	3
LEV	21-Jul-93	Om	FARM	240	548	1	2	4
LEV	22-Jul-93	Lc	MKYAUPST	320	938	2	1	
LEV	18-Aug-92	Lc	MKYADNST	311	934	1	1	2
LEV	22-Jul-93	C	MKYADNST	485	1300	1	1	3

River	Date	spp	Site	Length	Mass	Gender	GI	Age
LEV	21-Jul-93	Om	SETTLMNT	190	254	1	2	
LEV	18-Aug-92	C	MKYADNST	450	1117	1	3	2
LEV	22-Jul-93	C	MKYADNST	430	1000	2	2	
LEV	18-Aug-92	C	MKYADNST	430	865	2	2	2
LEV	22-Jul-93	Hv	MKYADNST	440	1720	2	4	3
LEV	21-Jul-93	Bm	FARM	360	1000	2	3	2
LEV	18-Aug-92	C	FARM	370	590	2	2	3
LEV	21-Jul-93	Om	SETTLMNT	170	194			
LEV	18-Aug-92	Lr	MKYADNST	342	1260	2	2	2
LEV	18-Aug-92	Lr	MKYADNST	282	747	1	1	2
LEV	21-Jul-93	C	FARM	430	900	1	6	3
LEV	21-Jul-93	C	SETTLMNT	395	800	2	1	3
LEV	18-Aug-92	Lr	MKYADNST	305	855	2	1	3
LEV	22-Jul-93	Lc	MKYAUPST	295	766	2	1	
LEV	18-Aug-92	Lc	MKYADNST	352	1209	1	2	
LEV	22-Jul-93	C	MKYAUPST	435	876	2	1	5
LEV	18-Aug-92	Lc	MKYADNST	350	1348	2	2	2
OLI	17-Feb-93	C	KLIPSPRT	475	1700	1	2	3
OLI	04-Nov-93	Om	ARABIE	230	495	2	3	
OLI	23-Jun-92	Lr	POSTSEL	230	429	1	2	
OLI	17-Feb-93	C	KLIPSPRT	530	1800	1	2	3
OLI	23-Jun-92	Bm	PRESEL	251	329	1	2	
OLI	17-Feb-93	C	KLIPSPRT	505	1700	1	2	3
OLI	23-Jun-92	Lr	PRESEL	231	331	2	1	2
OLI	23-Jun-92	C	POSTSEL	545	1900	2	1	
OLI	17-Feb-93	C	KLIPSPRT	535	1600	1	2	3
OLI	23-Jun-92	C	PRESEL	530	1400	1	2	
OLI	17-Feb-93	C	KLIPSPRT	550	2000	1	2	4
OLI	17-Feb-93	C	KLIPSPRT	470	1100			
OLI	17-Feb-93	C	KLIPSPRT	470	2000			
OLI	04-Nov-93	Om	ARABIE	260	786	1	3	
OLI	04-Nov-93	Om	ARABIE	260	764	1	4	3
OLI	04-Nov-93	Lr	ARABIE	254	462	1	4	
OLI	04-Nov-93	Om	ARABIE	224	463	2	4	
OLI	23-Jun-92	C	POSTSEL	580	2200	1	1	5
OLI	23-Jun-92	C	POSTSEL	584	2400	1	3	2
OLI	23-Jun-92	C	POSTSEL	510	2000	1	3	2
OLI	04-Nov-93	Om	ARABIE	234	572	2	5	
OLI	04-Nov-93	Lr	ARABIE	255	453	1	4	
OLI	04-Nov-93	Om	ARABIE	262	744	1	3	
OLI	04-Nov-93	Om	ARABIE	264	774	1	5	
OLI	04-Nov-93	Om	ARABIE	264	560	2	3	
OLI	17-Feb-93	C	KLIPSPRT	465	1000			
OLI	17-Feb-93	C	KLIPSPRT	550	1700	2	2	4
OLI	04-Nov-93	Om	ARABIE	265	910	1	3	
OLI	17-Feb-93	C	KLIPSPRT	500	1000			
OLI	17-Feb-93	Bm	KLIPSPRT	255	300	2	5	
OLI	17-Feb-93	C	KLIPSPRT	460	900			
OLI	23-Jun-92	C	PRESEL	600	2800	2	1	3
OLI	04-Nov-93	Lr	ARABIE	270	446	1	4	
OLI	23-Jun-92	C	POSTSEL	635	2700	1	3	
OLI	23-Jun-92	Om	POSTSEL	164	180	2	3	2
OLI	23-Jun-92	Om	PRESEL	177	205	1	3	
OLI	04-Nov-93	Om	ARABIE	243	682	2	3	3
OLI	04-Nov-93	C	ARABIE	476	1230	2	4	
OLI	23-Jun-92	C	PRESEL	466	2200	2	1	
OLI	23-Jun-92	C	POSTSEL	705	4500	2	1	3

River	Date	spp	Site	Length	Mass	Gender	GI	Age
OLI	23-Jun-92	C	POSTSEL	760	5250	1	3	3
OLI	17-Feb-93	C	KLIPSPRT	440	1000			
OLI	23-Jun-92	C	POSTSEL	760	5500	2	2	6
OLI	23-Jun-92	Bm	PRESEL	260	321	1	1	
OLI	17-Feb-93	C	KLIPSPRT	440	1000			
OLI	17-Feb-93	C	KLIPSPRT	440	1000			
OLI	23-Jun-92	C	POSTSEL	775	5600	1	4	3
OLI	04-Nov-93	Lr	ARABIE	280	651	2	5	
OLI	04-Nov-93	Om	ARABIE	280	933	1	4	4
OLI	17-Feb-93	Bm	KLIPSPRT	280	500	2	5	4
OLI	23-Jun-92	Lr	POSTSEL	280	704	2	1	
OLI	23-Jun-92	Lr	PRESEL	280	545	2	1	2
OLI	17-Feb-93	C	KLIPSPRT	480	1400			
OLI	17-Feb-93	C	KLIPSPRT	485	1100			
OLI	23-Jun-92	C	PRESEL	465	1200	1	2	
OLI	04-Nov-93	Lr	ARABIE	261	465	1	4	
OLI	23-Jun-92	C	PRESEL	797	5700	2	1	4
OLI	04-Nov-93	Om	ARABIE	262	771	1	4	
OLI	04-Nov-93	C	ARABIE	840	7500	2	5	
OLI	23-Jun-92	C	PRESEL	880	8000	1	4	3
OLI	17-Feb-93	C	KLIPSPRT	420	750	2	4	2
OLI	17-Feb-93	C	KLIPSPRT	420	914	2	6	2
OLI	17-Feb-93	C	KLIPSPRT	410	850			
OLI	04-Nov-93	Om	ARABIE	283	926	1	4	4
OLI	17-Feb-93	C	KLIPSPRT	400	673	1	2	
OLI	04-Nov-93	C	ARABIE	980	13000	2	4	4.5
OLI	17-Feb-93	C	KLIPSPRT	400	712	2	2	2
OLI	23-Jun-92	C	POSTSEL	600	2400	1	3	
OLI	17-Feb-93	C	KLIPSPRT	400	750	1	3	2
OLI	04-Nov-93	C	ARABIE	980	12000	2	5	5
OLI	23-Jun-92	Om	POSTSEL	191	262	1	3	3
OLI	17-Feb-93	Bm	KLIPSPRT	265	500	2	5	
OLI	04-Nov-93	C	ARABIE	1005	13000	1	4	
OLI	17-Feb-93	C	KLIPSPRT	390	500			
OLI	23-Jun-92	Om	PRESEL	190	228	1	3	2
OLI	23-Jun-92	Om	PRESEL	188	259	1	3	2
OLI	23-Jun-92	Lr	POSTSEL	290	842	2	2	
OLI	17-Feb-93	C	KLIPSPRT	390	660	1	2	2
OLI	23-Jun-92	Om	PRESEL	188	216	2	2	2
OLI	17-Feb-93	C	KLIPSPRT	385	641	1	3	2
OLI	17-Feb-93	C	KLIPSPRT	385	606	1	2	2
OLI	23-Jun-92	Om	POSTSEL	183	234	1	2	
OLI	17-Feb-93	C	KLIPSPRT	370	604	1	2	3
OLI	23-Jun-92	Om	POSTSEL	182	267	2	1	2
OLI	04-Nov-93	Lr	ARABIE	295	674	2	5	
OLI	04-Nov-93	Lr	ARABIE	295	708	2	5	
OLI	04-Nov-93	Cc	ARABIE	640	6000	2	5	
OLI	23-Jun-92	Lr	POSTSEL	242	391	2	1	
OLI	17-Feb-93	C	KLIPSPRT	450	1000			
OLI	23-Jun-92	Om	PRESEL	180	228	1	3	3
OLI	04-Nov-93	Lr	ARABIE	245	451	2	5	
OLI	23-Jun-92	Bm	POSTSEL	352	1075	2	2	2
OLI	17-Feb-93	C	KLIPSPRT	330	400			
OLI	23-Jun-92	Lc	POSTSEL	320	975	2	2	3
OLI	23-Jun-92	Lr	POSTSEL	310	974	2	1	
OLI	17-Feb-93	C	KLIPSPRT	310	300			

River	Date	spp	Site	Length	Mass	Gender	GI	Age
OLI	04-Nov-93	Lr	ARABIE	252	485	2	5	
OLI	23-Jun-92	Lc	POSTSEL	305	805	1	1	3
OLI	17-Feb-93	C	KLIPSPRT	320	377	1	1	1
OLI	25-Jun-92	Lr	MEETWAL	253	500	2		
OLI	28-Jun-92	Lr	VYEBOOM	254	380	2		
OLI	15-Aug-91	Bm	MEETWAL	306	650	2		
OLI	25-Jun-92	Lr	MEETWAL	285	600	2		
OLI	28-Jun-92	Lr	VYEBOOM	260	415			
OLI	15-Aug-91	Bm	MEETWAL	275	510	2		
OLI	25-Jun-92	Lr	MEETWAL	276	500	2		
OLI	28-Jun-92	Lr	VYEBOOM	245	325	2		
OLI	28-Jun-92	Lr	VYEBOOM	235	290			
OLI	28-Jun-92	Lr	VYEBOOM	234	280			
OLI	25-Jun-92	Om	SELATI	227	550	2		
OLI	28-Jun-92	Lr	VYEBOOM	225	280			
OLI	28-Jun-92	Lr	VYEBOOM	215	245			
OLI	25-Jun-92	Lr	MEETWAL	245	350	2		
OLI	28-Jun-92	Lr	VYEBOOM	194	200			
OLI	15-Aug-91	Bm	MEETWAL	314	610	2		
OLI	15-Aug-91	C	SELATI	437	580			
OLI	15-Aug-91	C	VYEBOOM	836	4120	1		
OLI	25-Jun-92	Om	SELATI	146	135	2		
OLI	25-Jun-92	C	BALULI	620	1070	2		
OLI	15-Aug-91	C	SELATI	586	1580	1		
OLI	28-Jun-92	C	VYEBOOM	420	580			
OLI	15-Aug-91	Bm	MEETWAL	318	610	2		
OLI	15-Aug-91	C	SELATI	577	1340	2		
OLI	25-Feb-92	C	BALULI	586	1391	1		
OLI	28-Jun-92	C	VYEBOOM	576	1540			
OLI	28-Jun-92	C	VYEBOOM	576	1360			
OLI	15-Aug-91	C	SELATI	576	1540	1		
OLI	25-Jun-92	Om	SELATI	160	155	2		
OLI	25-Feb-92	Lc	MEETWAL	418	1027	2		
OLI	15-Aug-91	C	BALULI	529	1150	2		
OLI	15-Aug-91	C	BALULI	527	1140	2		
OLI	15-Aug-91	C	VYEBOOM	523	1280	2		
OLI	15-Aug-91	C	SELATI	517	900	2		
OLI	25-Feb-92	Lc	MEETWAL	417	1295	2		
OLI	25-Jun-92	Om	SELATI	162	145	2		
OLI	15-Aug-91	C	SELATI	507	900	1		
OLI	25-Feb-92	C	MEETWAL			1		
OLI	15-Aug-91	Bm	MEETWAL	400	1110	2		
OLI	15-Aug-91	Bm	MEETWAL	385	1050	2		
OLI	25-Feb-92	C	BALULI	450	697	1		
OLI	25-Feb-92	C	BALULI	442	725	2		
OLI	25-Jun-92	C	BALULI	903	6200	1		
OLI	28-Jun-92	C	VYEBOOM	340	300			
OLI	28-Jun-92	C	VYEBOOM	840	4610	2		
OLI	15-Aug-91	C	BALULI	795	4060	1		
OLI	15-Aug-91	C	SELATI	434	570	1		
OLI	15-Aug-91	C	MEETWAL	570	1880	2		
OLI	15-Aug-91	Bm	MEETWAL	350	980	2		
OLI	25-Jun-92	C	MEETWAL	610	3400	2		
OLI	15-Aug-91	C	SELATI	556	1400	2		
OLI	25-Jun-92	Om	SELATI	150	140	2		
OLI	15-Aug-91	C	MEETWAL	546	1400	1		
OLI	15-Aug-91	Bm	MEETWAL	353	900	2		

River	Date	spp	Site	Length	Mass	Gender	GI	Age
OLI	25-Jun-92	C	MEETWAL	510	1420	2		
OLI	15-Aug-91	C	BALULI	503	860	1		
OLI	15-Aug-91	Bm	MEETWAL	360	800	2		
OLI	25-Feb-92	Lr	MEETWAL	364	628	2		
OLI	15-Aug-91	Bm	MEETWAL	365	950	2		
OLI	15-Aug-91	C	BALULI	545	930	1		
OLI	15-Aug-91	Bm	MEETWAL	368	990	2		
OLI	25-Feb-92	C	SELATI	762	2500	2		
OLI	15-Aug-91	C	MEETWAL	497	1110	2		
OLI	25-Feb-92	Lr	MEETWAL	370	718	2		
OLI	15-Aug-91	Bm	MEETWAL	374	950	2		
OLI	25-Feb-92	Lr	MEETWAL	375	688	2		
OLI	25-Feb-92	Lr	MEETWAL	379	743	2		
OLI	25-Jun-92	C	MEETWAL	1050	6200	1		
OLI	25-Jun-92	C	BALULI	885	4810	1		
OLI	25-Jun-92	C	MEETWAL	484	1200	2		
OLI	15-Aug-91	C	SELATI	515	1000	2		
OLI	25-Jun-92	Om	SELATI	158	145	2		
OLI	15-Aug-91	C	MEETWAL	471	850	2		
SAB	02-Jun-93	Bm	WEIR	366	1250	2	2	5
SAB	25-May-92	Lc	WEIR	293	753	2	2	
SAB	03-Jun-93	Bm	WEIR	384	1452	2	3	4
SAB	02-Jun-93	Bm	WEIR	287	550	1	1	
SAB	25-May-92	Lc	WEIR	287	674	-1	1	
SAB	25-May-92	Lc	WEIR	296	826	-1	1	
SAB	02-Jun-93	Bm	WEIR	392	1700	2	2	3
SAB	25-May-92	Bm	WEIR	283	562	2	2	
SAB	25-May-92	Si	WEIR	292	402	2	3	4
SAB	25-May-92	Lrd	WEIR	289	699	2	2	2
SAB	25-May-92	Lc	WEIR	295	748	-1	1	
SAB	25-May-92	Lc	WEIR	298	912	1	2	
SAB	25-May-92	Lc	WEIR	301	886	2	2	
SAB	03-Jun-93	Lr	WEIR	300	833	2	2	
SAB	25-May-92	Si	WEIR	282	345	2	2	
SAB	03-Jun-93	Bm	WEIR	332	963	2	3	3
SAB	03-Jun-93	Lr	WEIR	300	770	2	2	3
SAB	03-Jun-93	Hv	WEIR	350	860	2	2	2
SAB	03-Jun-93	Lr	WEIR	300	848	1	2	
SAB	25-May-92	Lc	WEIR	292	768	1	2	
SAB	25-May-92	Si	WEIR	281	327	2	3	3
SAB	03-Jun-93	Lr	WEIR	303	874	2	2	
SAB	25-May-92	Lc	WEIR	292	740	2	2	
SAB	03-Jun-93	Bm	WEIR	280	687	2	2	3
SAB	25-May-92	Si	WEIR	279	358	2	2	
SAB	25-May-92	C	WEIR	435	1078	2	4	2
SAB	02-Jun-93	Lr	WEIR	342	1100	2	1	3
SAB	02-Jun-93	Bm	WEIR	303	750	1	2	4
SAB	03-Jun-93	Lr	WEIR	304	932	2	2	3
SAB	25-May-92	Si	WEIR	289	352	2	2	
SAB	25-May-92	Lc	WEIR	333	1282	2	2	3
SAB	03-Jun-93	Bm	WEIR	332	1038	2	2	3
SAB	03-Jun-93	Lc	WEIR	290	809	2	2	2
SAB	25-May-92	Si	WEIR	272	287	2	2	
SAB	25-May-92	Si	WEIR	271	296	2	2	
SAB	25-May-92	Bm	WEIR	271	535	1	2	
SAB	25-May-92	Si	WEIR	169	90	1	1	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
SAB	25-May-92	Si	WEIR	269	265	2	2	
SAB	25-May-92	Si	WEIR	269	303	2	6	
SAB	03-Jun-93	Lr	WEIR	264	630	1	2	
SAB	25-May-92	Lrd	WEIR	264	463	2	6	
SAB	25-May-92	Si	WEIR	260	245	2	2	
SAB	25-May-92	Lm	WEIR	259	405	2	6	
SAB	25-May-92	Lm	WEIR	259	398	2	2	
SAB	25-May-92	Si	WEIR	253	256	2	2	
SAB	25-May-92	Si	WEIR	285	316	2	2	
SAB	25-May-92	Lrd	WEIR	250	391	2	2	
SAB	03-Jun-93	Lr	WEIR	284	771	1	1	
SAB	25-May-92	Mm	WEIR	250	173	1	4	
SAB	25-May-92	Si	WEIR	242	183	2	2	
SAB	25-May-92	Si	WEIR	242	203	2	2	
SAB	25-May-92	Lc	WEIR	330	1073	-1	1	2
SAB	25-May-92	Mm	WEIR	242	177	1	4	
SAB	03-Jun-93	Om	WEIR	240	581	1	3	2
SAB	03-Jun-93	Lc	WEIR	304	855	2	2	3
SAB	25-May-92	Bm	WEIR	282	576	1	2	
SAB	03-Jun-93	Lr	WEIR	328	1211	2	2	3
SAB	25-May-92	Mm	WEIR	237	155	1	3	
SAB	25-May-92	Mm	WEIR	237	159	1	4	
SAB	25-May-92	Lc	WEIR	307	1012	1	2	
SAB	25-May-92	Lm	WEIR	235	347	1	2	
SAB	25-May-92	Lc	WEIR	328	1084	2	2	
SAB	25-May-92	Lc	WEIR	320	1132	2	2	2
SAB	25-May-92	Mm	WEIR	231	141	1	3	
SAB	25-May-92	Lm	WEIR	230	285	1	3	
SAB	25-May-92	Mm	WEIR	229	147	1	4	
SAB	25-May-92	Lc	WEIR	327	1207	2	2	
SAB	25-May-92	Lc	WEIR	326	1127	2	2	
SAB	25-May-92	Bm	WEIR	308	753	1	2	3
SAB	25-May-92	Lc	WEIR	322	964	1	2	
SAB	25-May-92	Bm	WEIR	282	604	2	2	4
SAB	25-May-92	Lm	WEIR	228	293	1	2	
SAB	25-May-92	Lm	WEIR	228	318	1	2	
SAB	25-May-92	Mm	WEIR	228	151	1	4	
SAB	02-Jun-93	Bm	WEIR	310	1000	2	1	4
SAB	25-May-92	Lm	WEIR	227	252	1	2	
SAB	25-May-92	Si	WEIR	282	357	2	3	2
SAB	25-May-92	Mm	WEIR	226	147	1	4	
SAB	25-May-92	Bm	WEIR	224	255	2	2	
SAB	25-May-92	Lr	WEIR	317	984	2	2	
SAB	25-May-92	Si	WEIR	223	149	2	2	
SAB	02-Jun-93	C	WEIR	550	1900	1	2	2
SAB	25-May-92	Lr	WEIR	313	915	2	2	
SAB	25-May-92	Lm	WEIR	222	271	1	2	
SAB	03-Jun-93	Si	WEIR	310	502	2	3	2
SAB	25-May-92	Lc	WEIR	312	905	-1	1	
SAB	03-Jun-93	Hv	WEIR	312	605	2	2	2
SAB	03-Jun-93	Lc	WEIR	312	833	1	1	1
SAB	25-May-92	Lc	WEIR	282	716	1	1	
SAB	25-May-92	Mm	WEIR	222	126	1	3	
SAB	25-May-92	Lr	WEIR	222	289	-1	1	
SAB	25-May-92	Lr	WEIR	316	1027	2	4	3
SAB	25-May-92	Lc	WEIR	281	651	-1	1	
SAB	25-May-92	Mm	WEIR	222	140	1	4	

River	Date	spp	Site	Length	Mass	Gender	GI	Age
SAB	25-May-92	Mm	WEIR	220	134	1	4	
SAB	25-May-92	Si	WEIR	216	151	2	2	
SAB	03-Jun-93	Lc	WEIR	315	978	2	3	
SAB	03-Jun-93	Lc	WEIR	314	903	2	2	2
SAB	25-May-92	Lc	WEIR	281	636	-1	1	
SAB	25-May-92	Si	WEIR	214	124	1	1	
SAB	25-May-92	Mm	WEIR	212	118	1	4	
SAB	25-May-92	Mm	WEIR	209	115	1	2	
SAB	25-May-92	Si	WEIR	207	124	1	1	
SAB	03-Jun-93	C	WEIR	690	3750	2	2	
SAB	25-May-92	Si	WEIR	205	113	1	1	
SAB	25-May-92	Bm	WEIR	204	200	1	5	
SAB	25-May-92	Si	WEIR	203	107	1	1	
SAB	25-May-92	Mm	WEIR	202	111	1	4	
SAB	25-May-92	Lr	WEIR	314	958	2	2	
SAB	25-May-92	Si	WEIR	201	105	1	1	
SAB	03-Jun-93	Lr	WEIR	314	1026	2	2	3
SAB	25-May-92	Om	WEIR	201	326	2	2	
SAB	25-May-92	Lrd	WEIR	278	584	2	2	
SAB	25-May-92	Si	WEIR	200	97	1	1	
SAB	25-May-92	Si	WEIR	278	284	2	3	
SAB	25-May-92	Si	WEIR	198	107	1	1	
SAB	03-Jun-93	Om	WEIR	275	822	1	2	3
SAB	25-May-92	Si	WEIR	274	321	2	2	
SAB	25-May-92	Si	WEIR	197	102	1	1	
SAB	25-May-92	Si	WEIR	195	101	1	1	
SAB	25-May-92	Bm	WEIR	190	159	-1	1	
SAB	25-May-92	Mm	WEIR	239	160	1	3	

Appendix B2: Fish Stomach Content Data

River	Site	SPP	Date	Sex	Lenght	Weight	Gut wgt.	Cont wgt.	Fullness	Age	M	D	G	Z	B	I	S	F	P	Fe	BA	OTH	UAM	Total
BER	MISVERST	Cc	Oct-93	2	455	2800					0	0	0	0	0	0	10	0	90	0	0	0	0	100
BER	VOELVLEI	Cc	Oct-93	2	390	2030					0	0	0	0	0	5	30	0	65	0	0	0	0	100
CRO	CROC_HOT	C	Oct-90	1	56	2050	28.0	7.4	0.3	2		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	CROC_HOT	C	Oct-90	2	32	1050	12.9	4.2	0.3			0	0	0	0	70	0	0	20	0	0	0	10	100
CRO	CROC_HOT	C	Jan-90	2	53	1750	22.4	8.6	0.4	3		0	0	0	0	5	1	1	0	1	0	87	5	100
CRO	CROC_HOT	C	Mar-91	1	33	410	19.8	12.7	0.6	1		0	0	0	0	100	0	0	0	0	0	0	0	100
CRO	CROC_HOT	C	Oct-90	1	50	1200	29.2	17.4	0.6	2		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	CROC_HOT	C	Oct-90	1	56	1900	40.1	14.7	0.4	4		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	HENGL_CL	C	Jan-90	1	38	590	10.0	0.7	0.1	2		0	0	0	0	0	0	0	50	0	0	0	50	100
CRO	HENGL_CL	C	Jan-90	2	48	1350	47.0	33.7	0.7	2		0	0	0	0	0	0	0	0	0	0	99	1	100
CRO	HENGL_CL	C	Jan-90	2	46	1240	51.3	41.9	0.8	3		0	0	0	0	1	0	0	0	0	0	98	1	100
CRO	HENGL_CL	C	Oct-90	2	48	1325	16.2	2.9	0.2	2		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	HENGL_CL	C	Sep-92	2	420	1000	10.2	14.4	1.4		0	0	0	0	0	0	20	25	0	0	0	20	35	100
CRO	HENGL_CL	C	Sep-91	1	38	650	9.8	3.1	0.3	4		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	HENGL_CL	C	Sep-91	2	38	700	9.2	3.9	0.4	3		0	0	0	0	0	15	0	85	0	0	0	0	100
CRO	HENGL_CL	C	Jun-90	2	79	2350	108.0	71.7	0.7			0	0	0	0	0	0	100	0	0	0	0	0	100
CRO	HENGL_CL	C	Jan-90	2	46	1210	49.9	36.4	0.7			0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	HENGL_CL	C	Sep-91	1	34	500	8.2	3.7	0.5	2		0	0	0	20	0	10	0	70	0	0	0	0	100
CRO	HENGL_CL	Om	Mar-90	1	25	610	8.3	6.1	0.7	4		5	5	0	0	0	60	0	30	0	0	0	0	100
CRO	HENGL_CL	Sd	Oct-90	2	29	300	6.2	1.9	0.3	3		0	0	0	0	0	0	0	0	0	0	0	100	100
CRO	KPMUIDEN	C	Sep-91	1	46	1050	0.0	0.0		3		0	0	0	0	0	0	0	100	0	0	0	0	100
CRO	KPMUIDEN	C	Jan-90	2	44	1100	14.4	4.9	0.3	3		0	0	0	0	20	5	0	60	0	0	0	15	100
CRO	KPMUIDEN	C	Mar-91	2	45	1100	15.5	3.2	0.2	4		0	0	0	0	15	0	0	80	0	0	5	0	100
CRO	KPMUIDEN	C	Jan-90	1	63	2640	38.5	4.8	0.1	3		0	0	0	0	0	0	92	4	0	0	0	4	100
CRO	KPMUIDEN	C	Jun-90	2	46	1260	29.2	13.5	0.5	4		0	0	0	0	0	0	100	0	0	0	0	0	100
CRO	KPMUIDEN	Om	Jun-90	2	23	490	4.2	2.0	0.5	5		2	10	0	0	0	0	0	88	0	0	0	0	100
CRO	KPMUIDEN	Sd	Oct-90	2	22	210	5.0	1.7	0.3	2		0	0	0	0	0	0	0	0	0	0	0	100	100
CRO	KPMUIDEN	Sd	Sep-91	2	26	270	0.0	0.0				0	0	0	0	100	0	0	0	0	0	0	0	100
CRO	KPMUIDEN	Sd	Feb-90	0	0	0	9.0	2.9	0.3			0	0	0	0	0	0	0	0	0	0	99	1	100
CRO	KPMUIDEN	Sd	Sep-91	2	25	250	0.0	0.0				0	0	0	0	70	0	0	30	0	0	0	0	100
CRO	KPMUIDEN	Sz	Mar-90	0	0	0	1.3	0.1	0.1			0	0	0	0	0	0	0	100	0	0	0	0	100
CRO	KPMUIDEN	Tr	Jun-90	1	24	700	4.8	1.9	0.4	4		1	5	0	0	0	0	0	94	0	0	0	0	100
CRO	KPMUIDEN	Tr	Jun-90	1	21	460	1.5	0.1	0.1	5		1	1	0	0	0	0	0	98	0	0	0	0	100
CRO	KPMUIDEN	Tr	Jun-90	1	22	550	7.3	4.4	0.6	4		1	4	0	0	0	0	0	95	0	0	0	0	100
CRO	LIONS_CL	C	Mar-91	1	48	1290	15.8	2.7	0.2			0	0	0	0	2	0	0	0	0	0	98	0	100
CRO	LIONS_CL	C	Jun-90	2	29	240	2.1	0.1	0.0	1		0	0	0	0	0	0	0	50	0	0	0	50	100
CRO	LIONS_CL	C	Mar-91	1	48	1190	19.7	5.8	0.3	1		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	LIONS_CL	C	Mar-91	1	48	1150	19.6	8.4	0.4			0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	LIONS_CL	C	Jun-90	2	33	360	3.9	0.2	0.1	2		1	1	0	0	0	50	0	43	0	0	5	0	100

River	Site	SPP	Date	Sex	Lenght	Weight	Gut wgt.	Cont wgt.	Fullness	Age	M	D	G	Z	B	I	S	F	P	Fe	BA	OTH	UAM	Total
CRO	LIONS_CL	C	Mar-91	1	51	1650	60.2	36.0	0.6	3		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	LIONS_CL	C	Jan-90	2	38	640	2.6	0.2	0.1			0	0	0	0	0	0	0	40	0	0	0	60	100
CRO	LIONS_CL	C	Oct-90	1	48	1200	27.5	21.0	0.8	2		0	0	0	0	0	0	0	100	0	0	0	0	100
CRO	LIONS_CL	C	Mar-91	1	47	1850	18.0	0.2	0.0	5		0	0	0	0	100	0	0	0	0	0	0	0	100
CRO	LIONS_CL	C	Oct-90	2	50	1450	42.9	23.2	0.5	3		0	0	0	0	0	0	0	100	0	0	0	0	100
CRO	LIONS_CL	C	Mar-91	1	50	1420	24.0	9.2	0.4			0	0	0	0	5	0	0	0	0	0	55	40	100
CRO	LIONS_CL	C	Jan-91	1	32	420	17.2	11.5	0.7	2		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	LIONS_CL	C	Jan-90	2	39	690	5.2	1.7	0.3	2		0	0	0	0	50	1	0	0	1	0	0	48	100
CRO	LIONS_CL	C	Sep-91	2	42	850	7.7	1.5	0.2	4		0	0	0	0	0	50	0	50	0	0	0	0	100
CRO	MATAFFIN	C	Sep-92	2	550	2200	26.9	20.6	0.8		0	0	0	0	0	0	0	80	0	0	0	0	20	100
CRO	MATAFFIN	C	Mar-91	2	41	950	22.3	10.1	0.5	1		0	0	0	0	15	0	0	0	0	0	70	15	100
CRO	MATAFFIN	C	Jan-90	1	57	2200	23.2	5.2	0.2			0	0	0	0	15	1	0	64	0	0	0	20	100
CRO	MATAFFIN	C	Sep-92	2	620	3000	43.7	55.1	1.3		0	0	0	0	0	0	0	20	0	0	0	0	80	100
CRO	MATAFFIN	C	Jan-90	1	67	293	23.7	2.5	0.1	3		0	0	0	0	0	5	0	50	0	0	0	45	100
CRO	RVULETTS	C	Oct-90	1	63	2650	48.6	15.4	0.3	5		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	RVULETTS	C	Oct-90	1	52	1800	36.4.	16.5	0.5	4		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	RVULETTS	C	Oct-90	2	58	2050	34.4	15.8	0.5	4		0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	RVULETTS	C	Oct-90	1	63	2600	39.6	8.1	0.2			0	0	0	0	0	0	0	0	0	0	100	0	100
CRO	RVULETTS	C	Oct-90	2	61	2400	44.2	22.2	0.5			0	0	0	0	0	0	40	0	0	0	60	0	100
CRO	RVULETTS	C	Oct-90	2	52	1850	24.6	8.3	0.3	4		0	0	0	0	0	0	100	0	0	0	0	0	100
CRO	TENBOSCH	C	Jun-90	2	52	2025	22.0	3.5	0.2	3		1	1	0	0	20	5	1	72	0	0	0	0	100
CRO	TENBOSCH	C	Jan-90	2	52	1820	33.8	8.3	0.2			0	0	0	0	0	1	0	50	0	0	0	49	100
CRO	TENBOSCH	C	Jan-91	1	41	850	9.3	2.4	0.3	5		0	0	0	0	0	30	70	0	0	0	0	0	100
CRO	TENBOSCH	Om	Jun-90	2	28	875	4.9	0.6	0.1	7		1	1	0	0	0	0	0	98	0	0	0	0	100
CRO	TENBOSCH	Om	Sep-91	2	29	950	9.5	5.0	0.5	4		5	2	0	0	0	0	0	93	0	0	0	0	100
CRO	TENBOSCH	Om	Mar-91	2	30	1120	4.4	2.5	0.6	6		2	0	0	0	0	0	0	98	0	0	0	0	100
CRO	TENBOSCH	Om	Sep-91	1	29	940	11.1	6.0	0.5	5		4	2	0	0	0	0	0	94	0	0	0	0	100
CRO	TENBOSCH	Om	Sep-91	2	27	850	16.3	12.1	0.7	4		5	1	0	0	0	0	0	94	0	0	0	0	100
CRO	TENBOSCH	Om	Jun-90	2	23	550	6.6	4.7	0.7	4		5	5	0	0	0	0	0	90	0	0	0	0	100
CRO	TENBOSCH	Om	Sep-91	1	38	1010	12.4	9.2	0.7	5		9	1	0	0	0	0	0	90	0	0	0	0	100
CRO	TENBOSCH	Om	Sep-91	1	28	940	5.5	2.5	0.5	4		3	2	0	0	0	0	0	95	0	0	0	0	100
CRO	TENBOSCH	Om	Jan-90	1	29	1400	6.1	3.7	0.6	2		0	0	0	0	0	0	0	100	0	0	0	0	100
CRO	TENBOSCH	Om	Sep-91	1	27	910	3.9	1.6	0.4	4		5	2	0	0	0	0	0	93	0	0	0	0	100
CRO	TENBOSCH	Om	Sep-91	1	30	1050	4.9	1.9	0.4	6		2	2	0	0	0	0	0	96	0	0	0	0	100
CRO	TENBOSCH	Om	Mar-91	1	25	800	3.1	0.7	0.2	5		5	0	0	0	0	15	0	80	0	0	0	0	100
CRO	TENBOSCH	Om	Jan-90	2	29	770	3.4	1.5	0.4	4		0	0	0	0	0	0	0	99	1	0	0	0	100
CRO	TENBOSCH	Tr	Jun-90	1	27	920	24.9	20.1	0.8	6		0	1	0	0	0	1	0	98	0	0	0	0	100
CRO	TENBOSCH	Tr	Jun-90	1	26	900	16.1	10.7	0.7	5		0	1	0	0	0	0	0	99	0	0	0	0	100
CRO	TENBOSCH	Tr	Jun-90	1	19	310	4.3	2.0	0.5	2		2	4	0	0	0	0	0	94	0	0	0	0	100
CRO	TENBOSCH	Tr	Jan-90	2	25	740	1.9	0.0	0.0			0	0	0	0	0	10	0	90	0	0	0	0	100
CRO	TENBOSCH	Tr	Jan-90	1	31	1280	2.6	0.6	0.2	3		0	0	0	0	0	5	0	95	0	0	0	0	100

River	Site	SPP	Date	Sex	Lenght	Weight	Gut wgt.	Cont wgt.	Fullness	Age	M	D	G	Z	B	I	S	F	P	Fe	BA	OTH	UAM	Total
CRO	TENBOSCH	Tr	Mar-91	1	32	750	0.0	0.0		3.36		0	0	0	0	0	0	100	0	0	0	0	0	100
CRO	TENBOSCH	Tr	Sep-91	1	27	1000	4.1	1.2	0.3			2	2	0	0	0	1	0	95	0	0	0	0	100
CRO	TENBOSCH	Tr	Sep-91	2	23	810	7.1	4.1	0.6			2	2	0	0	0	0	0	96	0	0	0	0	100
CRO	TENBOSCH	Tr	Sep-91	2	24	750	8.1	5.5	0.7			1	2	0	0	0	0	0	95	2	0	0	0	100
CRO	TENBOSCH	Tr	Mar-90	2	29	760	2.8	0.7	0.3	3		0	0	0	0	1	20	0	79	0	0	0	0	100
CRO	TENBOSCH	Tr	Jun-90	1	27	1050	11.9	8.5	0.7	4		1	4	0	0	0	0	0	95	0	0	0	0	100
CRO	TENBOSCH	Tr	Jan-90	2	24	720	2.8	1.3	0.5			0	0	0	0	0	0	0	100	0	0	0	0	100
CRO	TENBOSCH	Tr	Sep-92	2	265	809	3.9	23.1	6.0		0	0	85	0	0	0	0	0	15	0	0	0	0	100
CRO	TENBOSCH	Tr	Sep-92	1	270	1024	3.3	13.5	4.1		10	10	75	0	0	0	0	0	5	0	0	0	0	100
CRO	TENBOSCH	Tr	Jan-90	1	31	1400	2.2	0.4	0.2	3		0	0	0	0	0	0	0	100	0	0	0	0	100
CRO	TENBOSCH	Tr	Jan-90	2	26	780	1.3	0.2	0.2	4		0	0	0	0	0	0	0	100	0	0	0	0	100
LET	DRIFT	Om	Aug-91	0	0	0	2.5	0.9	0.4			10	13	0	2	0	10	0	65	0	0	0	0	100
LET	HUDSON	C	May-93	2	370	545	6.0	6.0	1.0	2	0	0	0	0	0	0	0	0	0	0	0	0	100	100
LET	HUDSON	Om	May-93	1	170	186	0.5	0.5	1.0		0	0	0	0	0	0	0	0	100	0	0	0	0	100
LET	HUDSON	Om	May-93	1	154	128	0.5	1.5	3.0		0	0	50	0	0	0	50	0	0	0	0	0	0	100
LET	JUNCTION	C	Feb-90	0	0	0	15.9	1.2	0.1			0	0	20	3	0	1	0	56	0	0	0	20	100
LET	JUNCTION	C	Feb-90	0	0	0	28.8	8.7	0.3			0	0	0	0	0	5	0	0	0	0	85	10	100
LET	JUNCTION	C	Aug-90	1	63	2800	46.5	23.7	0.5	4		0	0	0	0	0	0	0	100	0	0	0	0	100
LET	JUNCTION	C	Aug-90	1	0	1430	25.6	9.6	0.4			0	0	0	0	0	0	0	100	0	0	0	0	100
LET	JUNCTION	C	Feb-90	0	0	0	20.8	7.9	0.4			0	0	0	5	0	15	0	80	0	0	0	0	100
LET	JUNCTION	Om	Jun-92	1	290	958	1.9	1.0	0.5		100	0	0	0	0	0	0	0	0	0	0	0	0	100
LET	JUNCTION	Om	Aug-90	2	26	680	3.5	1.3	0.4	4		1	4	0	0	0	0	0	95	0	0	0	0	100
LET	JUNCTION	Om	Feb-90	1	0	0	3.6	1.5	0.4			1	10	0	0	0	14	0	75	0	0	0	0	100
LET	JUNCTION	Om	May-91	2	21	450	6.7	5.0	0.7	3		2	30	0	0	0	0	0	68	0	0	0	0	100
LET	JUNCTION	Om	May-91	1	14	130	2.4	1.7	0.7	3		0	70	0	0	0	0	0	30	0	0	0	0	100
LET	JUNCTION	Om	May-91	1	23	520	9.8	7.0	0.7	3		1	50	0	0	0	0	0	48	0	0	0	1	100
LET	JUNCTION	Om	May-91	2	25	750	7.1	4.2	0.6	4		2	18	0	0	0	0	0	80	0	0	0	0	100
LET	JUNCTION	Om	Feb-90	0	0	0	2.2	1.1	0.5			1	3	0	0	0	6	0	90	0	0	0	0	100
LET	JUNCTION	Om	Feb-90	1	0	0	3.5	1.3	0.4			1	4	0	0	0	35	0	60	0	0	0	0	100
LET	JUNCTION	Om	Feb-91	2	26	750	3.1	0.9	0.3	4		1	0	0	0	0	0	0	99	0	0	0	0	100
LET	JUNCTION	Om	Feb-90	0	0	0	1.3	0.8	0.6			1	10	0	0	0	10	0	79	0	0	0	0	100
LET	JUNCTION	Om	Jun-92	2	250	517	0.7	4.3	6.3		50	20	2	0	0	0	28	0	0	0	0	0	0	100
LET	JUNCTION	Om	Jun-92	1	294	782	1.6	3.2	2.0		40	5	5	0	0	0	10	0	5	0	0	35	0	100
LET	JUNCTION	Om	Aug-90	2	25	680	2.7	0.1	0.0	4		0	3	0	0	0	0	0	97	0	0	0	0	100
LET	JUNCTION	Om	Feb-91	2	24	520	2.1	0.8	0.4	5		1	0	0	0	0	0	0	99	0	0	0	0	100
LET	JUNCTION	Om	Feb-91	2	27	770	2.1	0.8	0.4	4		2	0	0	0	0	0	0	97	0	0	0	1	100
LET	JUNCTION	Om	Feb-90	2	0	0	2.5	1.2	0.5			1	4	0	0	0	15	0	80	0	0	0	0	100
LET	JUNCTION	Om	Aug-90	1	23	570	3.3	1.3	0.4	3		0	20	0	0	0	0	0	80	0	0	0	0	100
LET	JUNCTION	Om	Nov-91	2	25	590	7.4	5.0	0.7	5		2	40	0	0	0	8	0	50	0	0	0	0	100
LET	JUNCTION	Om	Feb-90	0	0	0	4.7	2.1	0.4			0	2	0	0	0	8	0	90	0	0	0	0	100
LET	JUNCTION	Om	Aug-90	2	26	740	3.8	0.5	0.1	4		0	1	0	0	0	0	0	99	0	0	0	0	100

River	Site	SPP	Date	Sex	Lenght	Weight	Gut wgt.	Cont wgt.	Fullness	Age	M	D	G	Z	B	I	S	F	P	Fe	BA	OTH	UAM	Total
LET	JUNCTION	Om	Aug-90	2	24	480	6.7	3.9	0.6	3		2	20	0	0	0	0	0	78	0	0	0	0	100
LET	JUNCTION	Om	Feb-90	2	0	0	1.9	0.5	0.3			0	2	0	0	0	38	0	60	0	0	0	0	100
LET	JUNCTION	Om	Feb-90	2	0	0	2.9	1.4	0.5			0	1	0	0	0	50	0	49	0	0	0	0	100
LET	JUNCTION	Om	Jun-92	1	287	876	1.9	3.2	1.7		70	2	1	0	0	0	27	0	0	0	0	0	0	100
LET	JUNCTION	Sd	Jun-92	2	230	158	1.9	1.0	0.5		0	0	0	0	0	0	0	100	0	0	0	0	0	100
LET	JUNCTION	Tr	May-92	1	218	400	1.7	0.7	0.4		12	3	0	0	0	0	15	0	70	0	0	0	0	100
LET	MIDLET	Om	May-93	1	140	95	0.5	0.5	1.0		0	0	40	0	0	0	60	0	0	0	0	0	0	100
LET	MIDLET	Om	May-93	2	168	154	0.5	0.5	1.0		0	0	40	0	0	0	60	0	0	0	0	0	0	100
LET	MIDLET	Om	May-93	1	126	63	0.5	1.0	2.0		0	0	40	0	0	0	60	0	0	0	0	0	0	100
LET	MIDLET	Om	May-93	2	143	101	0.5	1.0	2.0		0	0	40	0	0	0	60	0	0	0	0	0	0	100
LET	PREISKAW	Om	Jun-92	1.33	208	372	1.0	0.5	0.6		90	0	0	0	0	0	0	0	10	0	0	0	0	100
LET	PREISKAW	Sd	Jun-92	2	212	147	1.8	0.7	0.4		0	0	0	0	0	25	20	35	0	0	0	0	20	100
LET	PRIESKAW	C	May-90	0	0	0	11.3	2.4	0.2			0	0	0	5	10	15	0	70	0	0	0	0	100
LET	PRIESKAW	C	Aug-90	1	55	2100	15.4	1.4	0.1	4		0	0	0	0	0	0	0	0	0	0	5	95	100
LET	PRIESKAW	C	Feb-90	0	0	0	7.4	0.9	0.1			0	0	0	0	10	20	0	40	0	0	0	30	100
LET	PRIESKAW	C	May-90	0	0	0	30.4	11.7	0.4			0	0	0	0	0	1	0	99	0	0	0	0	100
LET	PRIESKAW	C	Nov-91	0	0	0	0.0	0.0				0	0	0	0	0	0	0	0	0	0	0	0	0
LET	PRIESKAW	C	Nov-91	0	0	0	0.0	0.0				0	0	0	0	0	0	0	0	0	0	0	0	0
LET	PRIESKAW	C	Aug-90	1	58	1960	27.6	1.7	0.1	4		0	0	0	0	100	0	0	0	0	0	0	0	100
LET	PRIESKAW	C	May-90	0	0	0	15.4	1.2	0.1			0	0	0	0	0	1	0	99	0	0	0	0	100
LET	PRIESKAW	C	Nov-91	1	63	2500	47.5	15.2	0.3	7		5	2	0	0	0	10	5	0	0	0	78	0	100
LET	PRIESKAW	C	May-90	0	0	0	50.6	2.0	0.0			0	0	0	0	0	0	0	50	0	0	50	0	100
LET	PRIESKAW	Om	May-90	9	0	0	3.0	2.1	0.7			1	1	0	0	0	0	0	94	0	0	4	0	100
LET	PRIESKAW	Om	May-90	8	0	0	0.8	0.1	0.2			0	0	0	0	0	0	0	100	0	0	0	0	100
LET	PRIESKAW	Om	Feb-91	2	17	150	1.5 ·	0.8	0.6	1		1	0	0	0	0	0	0	94	0	0	0	5	100
LET	PRIESKAW	Om	Feb-91	1	17	155	1.0	0.1	0.1	1		1	0	0	0	0	2	0	97	0	0	0	0	100
LET	PRIESKAW	Om	Feb-91	2	18	175	1.1	0.5	0.4			2	0	0	0	0	0	0	98	0	0	0	0	100
LET	PRIESKAW	Om	Aug-90	1	22	0	1.9	0.4	0.2	1		0	30	0	0	0	0	0	70	0	0	0	0	100
LET	PRIESKAW	Om	Feb-90	0	0	0	1.8	0.9	0.5			1	2	0	0	0	0	0	97	0	0	0	0	100
LET	PRIESKAW	Om	May-90	11	0	0	1.0	0.1	0.1			1	1	0	0	0	0	0	98	0	0	0	0	100
LET	PRIESKAW	Om	Feb-91	1	17	110	1.2	0.1	0.1	1		0	0	0	0	0	10	1	88	0	0	0	1	100
LET	PRIESKAW	Om	Feb-91	2	21	210	0.5	0.2	0.3			2	0	0	0	0	0	0	98	0	0	0	0	100
LET	PRIESKAW	Om	May-91	2	23	240	3.2	1.6	0.5	4		20	5	0	0	0	5	0	70	0	0	0	0	100
LET	PRIESKAW	Om	May-91	1	21	220	4.3	2.4	0.6	3		20	5	0	0	0	40	0	35	0	0	0	0	100
LET	PRIESKAW	Om	May-91	1	21	350	1.8	0.3	0.2	4		5	5	0	0	0	0	0	90	0	0	0	0	100
LET	PRIESKAW	Om	May-91	2	23	300	4.7	2.2	0.5			5	5	0	0	0	10	0	80	0	0	0	0	100
LET	PRIESKAW	Om	May-91	1	22	230	4.7	3.4	0.7	4		5	2	0	0	0	43	0	50	0	0	0	0	100
LET	PRIESKAW	Om	May-91	2	16	140	10.3	7.6	0.7			4	2	0	0	0	34	0	60	0	0	0	0	100
LET	PRIESKAW	Om	Feb-91	1	18	180	1.6	0.7	0.4			1	0	0	0	0	30	0	69	0	0	0	0	100
LET	PRIESKAW	Om	Nov-91	1	22	372	1.6	0.4	0.3	4		10	15	0	0	0	10	0	65	0	0	0	0	100
LET	PRIESKAW	Om	Aug-91	2	19	300	3.7	2.8	0.8			5	1	0	0	0	14	0	80	0	0	0	0	100

River	Site	SPP	Date	Sex	Lenght	Weight	Gut wgt.	Cont wgt.	Fullness	Age	M	D	G	Z	B	I	S	F	P	Fe	BA	OTH	UAM	Total
LET	PRIESKAW	Om	Aug-91	1	23	470	2.7	1.2	0.5	4		8	2	0	0	0	10	0	80	0	0	0	0	100
LET	PRIESKAW	Om	Aug-91	2	24	480	8.2	4.3	0.5	4		2	3	0	0	0	50	0	45	0	0	0	0	100
LET	PRIESKAW	Om	Aug-91	2	20	320	1.5	0.5	0.3			6	4	0	0	0	10	0	80	0	0	0	0	100
LET	PRIESKAW	Om	Feb-91	1	17	170	1.2	0.4	0.3			2	0	0	0	0	1	0	97	0	0	0	0	100
LET	PRIESKAW	Om	May-90	7	0	0	2.1	0.2	0.1	2		1	2	0	0	0	0	0	97	0	0	0	0	100
LET	PRIESKAW	Om	Aug-91	2	20	320	1.3	0.6	0.4			4	1	0	1	0	5	0	89	0	0	0	0	100
LET	PRIESKAW	Om	Aug-91	2	18	240	1.2	0.3	0.2			5	0	0	0	0	10	0	85	0	0	0	0	100
LET	PRIESKAW	Sd	Aug-91	2	25	218	10.3	1.0	0.1			0	0	0	0	0	0	0	0	0	0	0	100	100
LET	PUMP	Sd	Jun-92	2	165	61	1.2	6.5	5.5		0	0	0	0	0	0	0	100	0	0	0	0	0	100
LET	PUMP	Sd	Jun-92	1	170	68	1.1	1.5	1.4		0	0	0	0	0	0	0	100	0	0	0	0	0	100
LET	PUMP_STA	C	Aug-90	2	29	280	8.9	5.0	0.6	1		0	0	0	0	0	0	0	20	0	0	0	80	100
LET	PUMP_STA	C	Aug-91	1	42	760	13.3	6.1	0.5	3		0	0	0	0	0	0	0	0	0	0	100	0	100
LET	PUMP_STA	C	Aug-91	1	39	700	34.5	17.5	0.5	3		0	0	0	0	0	0	0	0	0	0	100	0	100
LET	PUMP_STA	C	Aug-90	2	50	1505	102.8	75.1	0.7	6		0	0	0	0	0	0	0	0	0	0	100	0	100
LET	PUMP_STA	Om	May-91	1	26	990	5.7	3.6	0.6	7	1	5	25	0	0	0	17	0	50	0	0	0	2	100
LET	PUMP_STA	Om	May-91	1	28	1000	24.7	20.3	0.8	6	1	4	35	0	0	0	10	0	45	0	0	0	5	100
LET	PUMP_STA	Om	May-91	1	28	1000	9.9	7.1	0.7	4	1	4	14	0	0	0	30	0	50	0	0	0	1	100
LET	PUMP_STA	Om	May-91	1	20	400	10.5	8.7	0.8	4	1	5	27	0	0	0	5	0	60	0	0	0	2	100
LET	PUMP_STA	Om	Feb-91	2	19	200	2.5	1.1	0.4	3		1	0	0	0	0	0	0	98	0	0	0	1	100
LET	PUMP_STA	Om	Feb-91	1	19	220	1.5	0.5	0.3	2		5	0	0	0	0	0	0	95	0	0	0	0	100
LET	PUMP_STA	Om	May-91	1	28	1000	13.7	10.9	0.8	5	10	5	60	0	0	0	5	0	20	0	0	0	0	100
LET	PUMP_STA	Om	Aug-91	2	18	265	2.9	1.5	0.5	3		4	20	0	2	0	5	0	69	0	0	0	0	100
LET	PUMP_STA	Om	Aug-91	2	21	390	4.7	2.0	0.4	4		4	25	0	1	0	5	0	65	0	0	0	0	100
LET	PUMP_STA	Om	Aug-91	1	21	560	6.0	2.8	0.5	4		5	20	0	2	0	3	0	70	0	0	0	0	100
LET	PUMP_STA	Om	Aug-91	1	26	910	8.5	4.2	0.5	5		6	20	0	0	0	4	0	70	0	0	0	0	100
LET	PUMP_STA	Om	May-91	1	25	800	14.5	11.6	0.8	5	1	6	60	0	0	0	8	0	20	0	0	0	5	100
LET	PUMP_STA	Om	Nov-91	1	38	912	4.2	1.9	0.4	6		15	5	0	1	0	10	0	69	0	0	0	0	100
LET	PUMP_STA	Om	Aug-90	1	19	240	1.9	0.5	0.2	2		0	5	0	0	0	0	0	95	0	0	0	0	100
LET	PUMP_STA	Om	Aug-90	0	21	340	1.9	0.5	0.3	3		0	5	0	0	0	0	0	92	0	0	3	0	100
LET	PUMP_STA	Om	Nov-91	1	26	798	4.7	2.8	0.6	5		10	15	0	1	0	10	0	64	0	0	0	0	100
LET	PUMP_STA	Om	Nov-91	1	24	545	5.3	3.3	0.6	4		5	10	0	1	0	10	0	74	0	0	0	0	100
LET	PUMP_STA	Om	Nov-91	1	25	720	7.6	4.4	0.6	4		10	10	0	0	0	5	0	75	0	0	0	0	100
LET	PUMP_STA	Om	Aug-90	0	28	780	5.9	2.6	0.4	5		0	4	0	0	0	0	0	95	0	0	1	0	100
LET	PUMP_STA	Om	Nov-91	1	27	766	5.9	2.8	0.5	6		10	10	0	1	0	4	0	75	0	0	0	0	100
LET	PUMP_STA	Om	Nov-91	1	28	820	4.4	2.3	0.5	6		5	15	0	1	0	5	0	74	0	0	0	0	100
LET	PUMP_STA	Sz	Aug-90	2	18	100	1.6	0.2	0.1	2		0	0	0	0	50	0	0	0	0	0	0	50	100
LET	PUMP_STA	Sz	Aug-90	2	16	90	0.9	0.1	0.1	1		0	0	0	0	0	0	0	0	0	0	0	100	100
LET	PUMP_STA	Tr	Aug-90	1	14	100	1.0	0.2	0.2			1	2	0	5	0	0	0	92	0	0	0	0	100
LET	SLAB	C	Nov-91	1	55	1900	57.7	40.9	0.7	4		3	1	0	1	0	8	0	0	0	0	87	0	100
LET	SLAB	C	May-91	1	52	1900	26.1	5.5	0.2	4		0	0	0	15	0	10	0	75	0	0	0	0	100
LET	SLAB	C	Aug-90	2	38	660	6.5	0.6	0.1			0	0	5	0	10	15	0	0	0	0	0	70	100

River	Site	SPP	Date	Sex	Lenght	Weight	Gut wgt.	Cont wgt.	Fullness	Age	M	D	G	Z	B	I	S	F	P	Fe	BA	OTH	UAM	Total
LET	SLAB	C	Nov-91	1	41	800	23.3	11.4	0.5			0	0	0	0	0	0	0	0	0	0	100	0	100
LET	SLAB	C	Feb-90	0	0	0	11.3	2.8	0.2			0	0	0	0	0	10	0	0	0	0	70	20	100
LET	SLAB	C	Nov-91	1	53	1800	32.9	11.7	0.4			7	3	0	0	0	10	0	10	0	0	70	0	100
LET	SLAB	C	Aug-91	1	61	2720	64.7	36.6	0.6	7		0	0	0	0	0	0	0	0	0	0	100	0	100
LET	SLAB	Om	Feb-90	0	0	0	1.1	0.6	0.5			1	1	0	0	0	48	0	50	0	0	0	0	100
LET	SLAB	Om	May-91	2	20	260	10.2	6.7	0.7			5	5	0	0	0	15	0	75	0	0	0	0	100
LET	SLAB	Om	May-90	1	0	0	1.7	0.9	0.5			1	1	0	0	0	0	0	98	0	0	0	0	100
LET	SLAB	Om	Nov-91	1	25	665	7.0	4.4	0.6			35	5	0	0	0	10	0	50	0	0	0	0	100
LET	SLAB	Om	Feb-91	2	19	300	1.8	1.1	0.6	3		1	0	0	0	0	0	0	99	0	0	0	0	100
LET	SLAB	Om	Nov-91	1	23	469	3.0	1.3	0.4			15	2	0	1	0	35	0	47	0	0	0	0	100
LET	SLAB	Om	Nov-91	2	22	446	5.2	3.0	0.6	4		20	2	0	1	0	20	0	57	0	0	0	0	100
LET	SLAB	Om	May-91	1	23	400	2.9	0.8	0.3	4		5	0	0	0	0	3	0	92	0	0	0	0	100
LET	SLAB	Om	May-91	2	20	280	3.9	3.0	0.8			10	5	0	0	0	25	0	60	0	0	0	0	100
LET	SLAB	Om	Aug-91	1	25	691	16.1	11.0	0.7	5		1	4	0	0	0	20	0	75	0	0	0	0	100
LET	SLAB	Om	Nov-91	1	26	647	3.2	1.2	0.4	4		20	2	0	1	0	30	0	47	0	0	0	0	100
LET	SLAB	Om	Aug-91	2	22	406	4.4	2.3	0.5	4		14	1	0	0	0	15	0	70	0	0	0	0	100
LET	SLAB	Om	Aug-90	2	35	560	6.6	4.0	0.6			0	8	0	0	0	0	0	92	0	0	0	0	100
LET	SLAB	Om	May-91	1	23	550	2.2	0.4	0.2	4		40	5	0	0	0	35	0	20	0	0	0	0	100
LET	SLAB	Om	May-91	2	22	350	3.8	2.2	0.6	4		30	0	0	0	0	30	0	40	0	0	0	0	100
LET	SLAB	Om	Feb-90	0	0	0	0.8	0.2	0.3			0	0	0	0	0	50	0	50	0	0	0	0	100
LET	SLAB	Om	May-91	2	22	380	4.4	2.6	0.6	4		25	4	0	0	0	20	0	50	0	0	0	1	100
LET	SLAB	Om	May-91	2	23	280	5.8	4.1	0.7	3		70	5	0	0	0	17	0	8	0	0	0	0	100
LET	SLAB	Om	Aug-90	1	22	460	14.2	11.3	0.8	2		0	20	0	0	0	0	0	80	0	0	0	0	100
LET	SLAB	Om	Aug-91	2	16	149	1.5	0.5	0.3			5	1	0	0	0	10	0	84	0	0	0	0	100
LET	SLAB	Om	Aug-91	1	19	343	2.0	0.7	0.4	3		10	1	0	0	0	10	0	79	0	0	0	0	100
LET	SLAB	Om	Aug-91	2	23	411	4.4	2.2	0.5	3		5	2	0	0	0	20	0	73	0	0	0	0	100
LET	SLAB	Sd	Feb-90	0	0	0	9.0	2.9	0.3			0	0	0	0	0	0	0	0	0	0	99	1	100
LEV	FARM	C	Jul-93	1	430	900	12.0	15.0	1.3	4	0	0	0	0	0	0	0	0	50	0	0	0	50	100
LEV	MKYADNST	C	Jul-93	2	430	1000					0	0	0	0	0	0	80	0	20	0	0	0	0	100
LEV	MKYADNST	Om	Aug-92	1	175	242	0.7	0.7	1.1		60	0	40	0	0	0	0	0	0	0	0	0	0	100
OLI	ARABIE	Om	Nov-93	1	280	933	2.0	3.0	1.5	4	0	0	0	0	0	0	100	0	0	0	0	0	0	100
OLI	KLIPSPR	C	Feb-93	2	400	712	6.0	3.0	0.5	2	0	0	0	0	0	40	0	60	0	0	0	0	0	100
OLI	KLIPSPR	C	Feb-93	2	420	750	19.0	7.0	0.4	2	0	0	0	0	0	0	0	100	0	0	0	0	0	100
OLI	KLIPSPR	C	Feb-93	1	370	604	17.0	20.0	1.2	3	0	0	0	0	0	0	0	0	100	0	0	0	0	100
OLI	POSTSEL	C	Jun-92	2	775	5600	48.9	72.3	1.5		0	0	10	0	0	0	0	85	5	0	0	0	0	100
OLI	POSTSEL	Om	Jun-92	2	182	267	1.3	3.4	2.6		10	80	5	0	0	0	5	0	0	0	0	0	0	100
OLI	PRESEL	C	Jun-92	2	466	2200	34.0	22.6	0.7		80	0	10	0	0	0	0	10	0	0	0	0	0	100
OLI	PRESEL	C	Jun-92	2	600	2800	46.8	38.9	0.8		0	0	0	0	0	0	0	100	0	0	0	0	0	100
OLI	PRESEL	Om	Jun-92	2	797	5700	0.7	0.8	1.0		65	5	3	0	0	0	27	0	0	0	0	0	0	100
SAB	WEIR	Lr	Jun-93	2	314	1026				3	0	0	0	0	0	0	100	0	0	0	0	0	0	100
SAB	WEIR	Om	Jun-93	1	275	822	3.0	18.0	6.0	3	40	0	30	30	0	0	0	0	0	0	0	0	0	100

River	Site	SPP	Date	Sex	Lenght	Weight	Gut wgt.	Cont wgt.	Fullness	Age	M	D	G	Z	B	I	S	F	P	Fe	BA	OTH	UAM	Total
SAB	WEIR	Om	Jun-93	1	240	581	2 0	12.0	6 0	2	20	0	50	0	0	0	20	0	10	0	0	0	0	100
SAB	WEIR	Sd	May-92	2	271	296	3.2	5.5	1 7		0	0	0	0	0	0	0	45	55	0	0	0	0	100
SAB	WEIR	Sd	May-92	2	223	149	2.5	0.4	0.2		0	0	0	0	0	70	0	0	0	0	0	0	30	100
SAB	WEIR	Sd	May-92	2	281	327	7.2	0.5	0.1		0	0	0	0	0	0	0	100	0	0	0	0	0	100
SAB	WEIR	Sd	May-92	1	200	97	1.5	1.4	0.9		0	0	0	0	0	100	0	0	0	0	0	0	0	100

Appendix C
Metal Bioaccumulation Data

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Oct-92	BER	MISVERST	Om	LIVER	210	260	2	5		97.79	5.07	0.92			16.79			0.40	5.12		114.67		0.321
Oct-92	BER	MISVERST	Om	LIVER	220	350	2	6		66.04	5.77	0.73			100.58			0.40	4.56		105.92	0.049	0.350
Oct-92	BER	MISVERST	Om	LIVER	240	450	2	6		47.43	2.09	0.51			143.65			0.40	2.95		71.39	0.020	0.400
Oct-92	BER	MISVERST	Om	GILLS	353	520	1	5		237.41	0.30	0.90			3.63			0.40	24.67		75.36	0.006	0.432
Oct-92	BER	MISVERST	Om	LIVER	200	220	2	4		246.00	0.36	0.87			6.66			0.40	6.77		109.93	0.076	0.322
Oct-92	BER	MISVERST	Om	GILLS	220	350	2	6		114.34	3.31	1.07			4.96			0.40	43.82		96.65	0.003	0.259
Oct-92	BER	MISVERST	Om	LIVER	220	258	2	5		76.72	0.43	0.86			39.40			0.40	3.02		92.07	0.027	0.350
Oct-92	BER	VOELVLEI	Cc	LIVER	455	3000	1	6	8	38.44	1.78	0.56			99.48			0.40	4.38		169.83	0.120	0.433
Oct-92	BER	VOELVLEI	Cc	GILLS	455	3000	1	6	8	101.16	0.96	1.45			5.54			0.40	161.56		369.89	0.053	0.232
Oct-92	BER	VOELVLEI	Cc	LIVER	460	2600	1	6	4	16.38	1.69	0.88			125.23			0.40	3.08		186.24	0.032	0.393
Oct-92	BER	VOELVLEI	Cc	LIVER	510	3750	1	6	8	23.97	3.14	2.71			151.88			0.40	4.59		237.27	0.117	0.304
Oct-92	BER	VOELVLEI	Om	LIVER	260	550	1	5	4	32.35	3.84	0.71			259.28			0.40	3.18		100.27	0.114	0.339
Oct-92	BER	VOELVLEI	Om	EGGS	260	550	1	5	4	55.73	6.49	1.18			4.92			0.40	18.24		94.89	0.007	0.312
Oct-93	BER	MISVERST	Cc	GILLS	455	2800	2	4.5		79.72		0.50			8.61			0.60	90.05		374.97		0.244
Oct-93	BER	MISVERST	Cc	LIVER	455	2800	1	4.5		35.02		0.34			297.21			0.60	8.86		381.81		0.261
Oct-93	BER	MISVERST	Cc	LIVER	334	732	2	4		83.33		0.55			51.30			0.60	20.91		142.65		0.248
Oct-93	BER	MISVERST	Cc	LIVER	290	599	1	2	2	655.56		0.74			83.24			0.60	34.86		228.19		0.270
Oct-93	BER	MISVERST	Ms	LIVER	330	1143	1	4	2	24.09		0.50			14.78			0.60	9.68		115.86		0.271
Oct-93	BER	MISVERST	Ms	GILLS	330	1143	1	4	2	154.37		0.50			2.57			0.60	13.81		56.13		0.358
Oct-93	BER	MISVERST	Om	LIVER	284	845	2	4.5	3	35.52		0.50			3.93			0.60	3.14		52.26		0.438
Oct-93	BER	MISVERST	Om	GILLS	245	650	1	4	2.5	35.83		0.50			4.06			0.60	20.48		76.76		0.334
Oct-93	BER	MISVERST	Om	LIVER	246	699	1	4	2	30.25		0.50			74.64			0.60	2.84		51.79		0.375
Oct-93	BER	MISVERST	Om	LIVER	215	446	2	4		61.07		0.50			11.00			0.60	5.11		41.92		0.451
Oct-93	BER	MISVERST	Om	GILLS	246	699	1	4	2	62.64		0.50			2.82			0.60	24.67		55.83		0.371
Oct-93	BER	MISVERST	Om	LIVER	245	576	1	4	2	29.14		0.50			193.88			0.60	2.51		68.07		0.371
Oct-93	BER	MISVERST	Om	GILLS	245	587	1	4	1.5	61.34		0.50			4.10			0.60	27.45		74.66		0.273
Oct-93	BER	MISVERST	Om	GILLS	215	446	2	4		72.92		0.50			4.46			0.60	22.92		71.71		0.285
Oct-93	BER	MISVERST	Om	LIVER	245	587	1	4	1.5	53.79		0.50			37.02			0.60	3.31		50.81		0.467
Oct-93	BER	MISVERST	Om	LIVER	245	650	1	4	2.5	38.97		0.50			252.12			0.60	4.18		98.07		0.344
Oct-93	BER	MISVERST	Om	GILLS	284	845	2	4.5	3	266.35		0.50			2.73			0.60	34.23		74.46		0.343
Oct-93	BER	VOELVLEI	Cc	LIVER	390	2030	2	4		23.44		0.30			70.73			0.60	7.31		195.82		0.390
Oct-93	BER	VOELVLEI	Cc	GILLS	390	2030	2	4		21.44		0.50			3.91			0.60	152.80		401.59		0.227
Oct-93	BER	VOELVLEI	Md	GILLS	348	923	2	5	3	12.21		0.50			6.08			0.60	4.03		49.23		0.378
Oct-93	BER	VOELVLEI	Md	LIVER	348	923	2	5	3	12.21		0.23			3.13			0.60	7.37		96.34		0.264
Jun-89	CRO	LIONS_CL	C	FAT	788.3	5466.7	1.3	4				0.13	0.20	0.32	0.58	14.75		0.62	0.29	0.72	1.99		
Jun-89	CRO	LIONS_CL	C	FLESH	788.3	5466.7	1.3	4				0.13	1.77	0.32	2.99	131.97		0.62	2.72	0.68	61.82		
Jun-89	CRO	LIONS_CL	C	FAT	569.5	2050	1	3.75				0.13	0.83	0.32	1.32	47.84		0.62	0.69	1.11	3.92		
Jun-89	CRO	LIONS_CL	C	FLESH	569.5	2050	1	3.75				0.13	1.73	0.32	5.35	67.61		0.62	3.15	0.47	14.81		
Jun-89	CRO	LIONS_CL	C	FLESH	392	660.6	1.8	1.8				0.13	2.23	0.32	3.42	114.58		0.62	10.42	1.19	25.83		
Jun-89	CRO	LIONS_CL	C	LIVER	569.5	2050	1	3.75				0.66	2.48	0.32	12.05	2495.05		0.62	3.30	1.65	25.41		
Jun-89	CRO	LIONS_CL	C	LIVER	392	660.6	1.8	1.8				0.13	13.90	0.32	128.84	922.11		0.62	6.32	0.84	219.16		
Jun-89	CRO	LIONS_CL	C	LIVER	398	691.7	2	2				0.13	4.06	0.32	50.86	6147.44		0.62	6.41	0.43	135.41		
Jun-89	CRO	LIONS_CL	Si	FLESH	252	215	2	2				0.13	2.29	0.32	3.11	109.62		0.62	8.18	1.31	39.71		
Jun-89	CRO	LIONS_CL	Si	LIVER	252	215	2	2				0.13	4.43	0.32	46.13	1793.36		0.62	7.38	0.74	104.13		

Date	River	Site	spp	Tissue	Length	Mass	Gender	Gl	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Jun-89	CRO	MATAFFIN	C	FLESH	587	2260	2	5				0.13	1.67	0.32	1.39	47.35		0.62	1.39	1.25	16.66		
Jun-89	CRO	RVERSIDE	Bm	LIVER	367.2	1212	2	2.6				0.13	2.58	0.32	24.35	662.36		0.62	11.07	1.48	87.40		
Jun-89	CRO	RVERSIDE	Bm	EGGS	367.2	1212	2	2.6				0.13	2.00	0.32	4.30	235.02		0.62	10.75	1.69	409.25		
Jun-89	CRO	RVERSIDE	Bm	FAT	367.2	1212	2	2.6				0.13	0.50	0.32	1.49	152.63		0.62	6.60	1.49	6.58		
Jun-89	CRO	RVERSIDE	Bm	FLESH	416	1780	2	2				0.13	0.75	0.32	0.59	15.88		0.62	0.42	0.46	4.50		
Jun-89	CRO	RVERSIDE	C	FLESH	634.6	3298	1.4	2.6				0.13	1.54	0.32	1.96	127.27		0.62	6.99	0.70	16.10		
Jun-89	CRO	RVERSIDE	C	LIVER	634.6	3298	1.4	2.6				0.13	4.36	0.32	105.46	17570.91		0.62	7.27	0.36	186.18		
Jun-89	CRO	RVERSIDE	Lm	LIVER	300	660	2	3.5				0.13	5.85	0.32	2064.12	585.24		0.62	33.08	2.04	96.51		
Jun-89	CRO	RVERSIDE	Lm	FLESH	300	660	2	3.5				0.13	2.59	0.32	2.59	72.93		0.62	6.48	1.14	24.99		
Jun-89	CRO	TENBOSCH	C	FLESH	624	2420	1	2				0.13	1.67	0.32	3.21	134.96		0.62	3.86	0.51	41.94		
Jun-89	CRO	TENBOSCH	C	LIVER	624	2420	1	2				0.13	4.85	0.32	56.46	3899.08		0.62	8.82	2.65	151.86		
Jun-89	CRO	TENBOSCH	Hv	LIVER	329	540	1	1				0.13	4.89	0.32	64.17	5029.32		0.62	16.29	1.63	144.95		
Jun-89	CRO	TENBOSCH	Hv	FLESH	329	540	1	1				0.13	1.69	0.32	3.26	80.73		0.62	9.12	1.17	17.67		
Jun-89	CRO	TENBOSCH	Om	FLESH	327	1340	1	5				0.13	2.28	0.32	2.58	45.59		0.62	3.04	1.06	25.68		
Jun-89	CRO	TENBOSCH	Om	EGGS	319	1220	2	5				0.13	0.83	0.32	4.97	55.00		0.62	4.14	0.47	110.74		
Jun-89	CRO	TENBOSCH	Om	TESTES	325	1280	1	4.7				0.13	2.71	0.32	5.63	156.25		0.62	2.08	1.25	78.04		
Jun-89	CRO	TENBOSCH	Om	LIVER	309.7	1133.3	1.3	4				0.13	2.55	0.32	502.38	1843.54		0.62	17.01	1.70	50.70		
Sep-89	CRO	CROC_HOT	Bm	FAT	320	855	2	5				0.02	0.27		0.43	96.90			2.27	1.23	2.91		
Sep-89	CRO	CROC_HOT	Bm	FLESH	320	855	2	5				0.02	0.14		1.44	34.80			1.56	1.13	12.91		
Sep-89	CRO	CROC_HOT	Bm	LIVER	320	855	2	5				0.02	0.03		9.25	166.40			10.29	1.06	47.35		
Sep-89	CRO	CROC_HOT	Bm	EGGS	320	855	2	5				0.02	0.03		4.45	45.90			6.89	0.83	124.61		
Sep-89	CRO	CROC_HOT	Lm	FLESH	306	730	1	4				0.02	0.58		2.06	79.00			3.83	1.39	19.64		
Sep-89	CRO	HNGEL_CL	Bm	FAT	367	1350	2	3.5				0.02	2.48		1.11	275.00			7.76	2.13	7.29		
Sep-89	CRO	HNGEL_CL	Bm	EGGS	367	1350	2	3.5				0.02	0.24		2.49	92.60			1.59	0.97	137.25		
Sep-89	CRO	HNGEL_CL	Bm	LIVER	367	1350	2	3.5				0.02	0.36		10.99	479.80			5.16	1.97	102.65		
Sep-89	CRO	HNGEL_CL	Bm	FLESH	367	1350	2	3.5				0.02	0.45		1.85	28.30			1.20	0.77	15.47		
Sep-89	CRO	HNGEL_CL	Bm	TESTES	221.6	257.3	1	3.5				0.02	1.36		2.16	44.60			1.36	1.26	61.38		
Sep-89	CRO	HNGEL_CL	C	LIVER	320	310	1	2				0.25	0.60		42.45	1615.10			7.75	3.35	124.40		
Sep-89	CRO	HNGEL_CL	C	TESTES	515	1613	1	4.7				0.08	2.31		4.91	156.20			12.98	1.74	82.35		
Sep-89	CRO	HNGEL_CL	C	LIVER	308	314	1.5	1.5				0.29	1.96		45.46	13719.70			4.32	0.71	103.25		
Sep-89	CRO	HNGEL_CL	C	FLESH	320	310	1	2				0.02	0.49		1.18	25.80			0.79	1.23	17.60		
Sep-89	CRO	HNGEL_CL	C	EGGS	390	620	1	1				0.02	1.65		7.31	407.20			6.69	1.04	173.22		
Sep-89	CRO	HNGEL_CL	C	FLESH	560.7	1815	1	4				0.02	0.04		1.28	38.60			0.33	0.71	23.44		
Sep-89	CRO	HNGEL_CL	Lm	EGGS	376	1800	2	5				0.02	0.26		6.70	252.30			1.31	0.80	208.36		
Sep-89	CRO	HNGEL_CL	Lm	FLESH	376	1800	2	5				0.02	0.63		2.97	52.20			2.10	0.84	26.89		
Sep-89	CRO	HNGEL_CL	Lm	LIVER	376	1800	2	5				2.79	1.12		70.98	166.30			18.05	1.18	201.84		
Sep-89	CRO	LIONS_CL	Bm	EGGS	366	1250	2	5				0.02	1.07		5.76	48.00			2.35	1.28	127.86		
Sep-89	CRO	LIONS_CL	Bm	FLESH	366	1250	2	5				0.02	1.80		2.01	53.00			17.15	1.32	24.52		
Sep-89	CRO	LIONS_CL	Bm	LIVER	366	1250	2	5				0.02	1.37		17.17	582.70			30.34	1.54	97.71		
Sep-89	CRO	LIONS_CL	C	TESTES	585	2120	1	4				0.23	2.73		4.86	105.40			22.69	2.36	77.59		
Sep-89	CRO	LIONS_CL	C	LIVER	645	2640	1	4				1.13	9.86		79.22	11153.40			20.71	0.78	137.24		
Sep-89	CRO	LIONS_CL	C	FLESH	645	2640	1	4				0.02	1.45		1.13	58.40			2.77	1.40	17.18		

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Sep-89	CRO	LIONS_CL	Lm	LIVER	290	650	2	4				0.41	2.32		260.66	164.30			41.02	1.18	59.78		
Sep-89	CRO	LIONS_CL	Lm	FLESH	290	650	2	4				0.02	0.27		1.40	24.40			2.06	1.03	12.68		
Sep-89	CRO	LIONS_CL	Lm	EGGS	290	650	2	4				0.02	0.34		10.28	305.00			2.40	1.11	212.80		
Sep-89	CRO	RVERSIDE	Bm	LIVER	340	1000	2	5				0.13	1.92		12.28	2299.40			10.24	1.86	95.91		
Sep-89	CRO	RVERSIDE	Bm	FLESH	340	1000	2	5				0.02	0.40		1.58	57.90			1.41	1.08	12.91		
Sep-89	CRO	RVERSIDE	Bm	EGGS	340	1000	2	5				0.02	0.48		2.79	95.50			2.44	1.01	206.53		
Sep-89	CRO	RVERSIDE	C	EGGS	475	1380	2	5				0.02	1.30		5.63	246.60			11.43	0.97	152.73		
Sep-89	CRO	RVERSIDE	C	FLESH	525	1760	2	2				0.02	0.53		1.37	67.50			2.29	1.14	16.31		
Sep-89	CRO	RVERSIDE	C	LIVER	525	1760	2	2				0.19	0.42		27.06	2400.50			12.83	0.87	106.30		
Sep-89	CRO	RVERSIDE	Lm	EGGS	376	1680	2	4				0.02	0.79		7.59	380.70			5.50	1.18	174.06		
Sep-89	CRO	RVERSIDE	Lm	FLESH	376	1680	2	4				0.02	0.79		3.21	122.80			5.37	1.06	28.33		
Sep-89	CRO	RVERSIDE	Lm	LIVER	334	1155	2	4.25				2.38	3.14		643.21	738.20			37.99	2.21	49.06		
Sep-89	CRO	RVERSIDE	Tr	FLESH	246	660	1	5				0.02	0.30		1.57	18.20			0.99	0.79	19.10		
Sep-89	CRO	RVERSIDE	Tr	LIVER	246	660	1	5				0.08	2.01		278.66	689.20			7.20	3.56	155.36		
Sep-89	CRO	TENBOSCH	C	EGGS	435	1120	2	3				0.02	0.18		6.95	173.90			11.05	0.54	119.86		
Sep-89	CRO	TENBOSCH	C	LIVER	655	3260	1	5				0.59	0.52		68.39	1676.80			7.03	1.54	138.64		
Sep-89	CRO	TENBOSCH	C	FLESH	655	3260	1	5				0.02	0.38		2.60	100.70			1.82	1.49	17.55		
Sep-89	CRO	TENBOSCH	C	TESTES	655	3260	1	5				0.02	0.37		6.54	105.00			31.45	1.84	90.59		
Sep-89	CRO	TENBOSCH	Om	FAT	297	980	1.7	4.7				0.02	0.22		0.28	11.60			0.85	0.61	3.11		
Sep-89	CRO	TENBOSCH	Om	FLESH	310	1200	1	5				0.02	0.18		2.16	33.00			2.62	1.14	22.90		
Sep-89	CRO	TENBOSCH	Om	LIVER	297	980	1.7	4.7				0.85	0.34		15.79	2398.00			15.73	2.28	92.66		
Sep-89	CRO	TENBOSCH	Om	TESTES	310	1200	1	5				0.02	1.13		13.38	248.90			12.25	3.87	99.44		
Sep-89	CRO	TENBOSCH	Om	EGGS	295	880	2	5				0.02	0.19		5.45	74.20			3.16	0.66	117.14		
Sep-89	CRO	TENBOSCH	Tr	FLESH	315	1440	2	4				0.02	0.28		1.22	15.90			1.13	0.87	16.18		
Sep-89	CRO	TENBOSCH	Tr	EGGS	315	1440	2	4				0.02	0.12		3.01	60.90			2.72	0.67	109.23		
Sep-89	CRO	TENBOSCH	Tr	LIVER	315	1440	2	4				0.02	0.44		53.84	312.60			4.36	1.33	57.58		
Sep-89	CRO	TENBOSCH	Tr	TESTES	275	880	1	4				0.02	0.38		8.21	133.40			20.38	2.39	96.96		
Sep-89	CRO	TENBOSCH	Tr	FAT	282	1040	1.7	4				0.02	0.30		0.31	30.60			1.72	0.66	5.87		
Jan-90	CRO	CROC_HOT	Bm	LIVER	327	985	2	5				0.61	2.81		18.88	228.52			7.24	0.36	79.29		0.220
Jan-90	CRO	CROC_HOT	Bm	FLESH	327	985	2	5				0.22	0.94		2.06	17.26			1.07	0.19	16.25		0.200
Jan-90	CRO	CROC_HOT	C	EGGS	534	1750	2	4	3							235.66					98.28		0.320
Jan-90	CRO	CROC_HOT	C	FLESH	534	1750	2	4	3			0.19	0.95		1.26	27.11			0.81	0.27	12.78		0.240
Jan-90	CRO	CROC_HOT	C	LIVER	534	1750	2	4	3			0.66	2.64		21.62	464.20			5.41	0.30	58.80		0.250
Jan-90	CRO	HNGEL_CL	Bm	TESTES	215	230	1	3								68.82					104.22		0.270
Jan-90	CRO	HNGEL_CL	Bm	LIVER	215	230	1	5				0.53	3.86		8.84	238.64			8.72	2.67	67.24		0.270
Jan-90	CRO	HNGEL_CL	Bm	FLESH	210	200	1	3				0.18	1.21		2.19	13.30			1.71	0.37	16.06		0.210
Jan-90	CRO	HNGEL_CL	Bm	FLESH	210	200	1	3				0.18	1.31		1.67	70.45			2.95	0.60	18.76		0.200
Jan-90	CRO	HNGEL_CL	C	EGGS	393	690	2	5	2							156.53					68.15		0.420
Jan-90	CRO	HNGEL_CL	C	FLESH	393	690	2	5	2			0.20	1.82		1.82	72.20			2.24	0.55	20.91		0.180
Jan-90	CRO	HNGEL_CL	C	LIVER	386	665	2	5	2			1.81	4.83		40.34	1433.19			9.22	1.47	112.24		0.180
Jan-90	CRO	LIONS_CL	C	FLESH	535	2720	2	4	3			0.18	1.18		1.50	30.39			3.00	0.42	26.85		0.200

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Jan-90	CRO	LIONS_CL	C	LIVER	535	2720	1	4	3			0.38	1.66		16.01	704.22			6.71	0.26	35.53		0.290
Jan-90	CRO	LIONS_CL	C	EGGS	475	1350	2	4	2							272.77					89.64		0.360
Jan-90	CRO	MATAFFIN	Bm	LIVER	319	800	2	4				0.84	3.14		14.91	222.09			7.60	1.81	60.91		0.220
Jan-90	CRO	MATAFFIN	Bm	FLESH	319	800	2	4				0.20	0.93		1.62	21.59			2.30	0.31	14.43		0.230
Jan-90	CRO	MATAFFIN	Bm	FLESH	319	800	2	4				0.29	3.38		1.62	53.44			2.31	0.33	15.64		0.210
Jan-90	CRO	MATAFFIN	Bm	LIVER	319	800	2	4				1.06	2.78		408.35	116.05			7.24	1.16	63.09		0.280
Jan-90	CRO	MATAFFIN	Bm	EGGS	319	800	2	4								81.74					65.92		0.400
Jan-90	CRO	MATAFFIN	C	LIVER	665	2930	1	5	3			0.77	4.83		8.95	1614.20			6.71	2.03	54.20		0.230
Jan-90	CRO	MATAFFIN	C	FLESH	665	2930	1	5	3			0.20	1.46		1.35	63.22			2.52	0.49	17.39		0.200
Jan-90	CRO	MATAFFIN	Lm	EGGS	366	1180	2	4								79.21					67.21		0.390
Jan-90	CRO	MATAFFIN	Lm	FLESH	366	1180	2	4				0.18	1.23		1.98	21.95			5.60	0.49	17.75		0.230
Jan-90	CRO	RVERSIDE	C	EGGS	435	1100	2	4	3							265.02					85.80		0.350
Jan-90	CRO	RVERSIDE	C	FLESH	632	2640	1	4	3			0.16	1.14		1.25	16.38			1.12	0.51	16.15		0.190
Jan-90	CRO	RVERSIDE	C	LIVER	632	2640	1	1	3			0.97	4.01		57.36	1335.93			7.16	1.15	99.71		0.260
Jan-90	CRO	RVERSIDE	Lc	FLESH	375	1240	2	2				0.20	1.10		1.40	28.32			2.88	0.20	19.29		0.190
Jan-90	CRO	TENBOSCH	C	LIVER	522	1820	2	4				1.91	3.75		130.77	616.68			8.49	0.86	131.08		0.190
Jan-90	CRO	TENBOSCH	Lc	FLESH	346	1130	1	5				0.25	1.07		1.58	22.60			2.52	0.62	19.59		0.190
Jan-90	CRO	TENBOSCH	Om	LIVER	284.5	755	2	4.5				4.23	3.10		281.79	1228.93			43.75	3.27	83.57		0.200
Jan-90	CRO	TENBOSCH	Om	LIVER	316	965	1	5	4			2.20	3.04		166.25	1323.94			20.62	2.48	66.42		0.260
Jan-90	CRO	TENBOSCH	Om	FLESH	292	1400	1	3	2			0.29	1.29		1.26	17.81			0.88	0.63	30.18		0.180
Jan-90	CRO	TENBOSCH	Tr	EGGS	251.5	745	2	4								78.80					83.04		0.420
Jan-90	CRO	TENBOSCH	Tr	FLESH	305	1400	1	4	3			0.14	1.41		1.08	9.49			0.61	0.31	17.85		0.250
Jan-90	CRO	TENBOSCH	Tr	LIVER	251.3	743.3	2	4.3				0.89	3.62		109.69	385.35			18.94	1.00	106.91		0.250
Jan-90	CRO	TENBOSCH	Tr	LIVER	305	1400	1	4	3			0.88	4.00		130.29	182.59			7.94	2.06	93.88		0.250
Jan-90	CRO	TENBOSCH	Tr	FLESH	262	780	2	4	4			0.12	0.92		1.10	9.88			0.73	0.25	12.01		0.240
Mar-90	CRO	CROC_HOT	C	LIVER	443	1150	1	3	2			0.71	1.34		49.14	10.30			4.43	0.81	52.31		0.222
Mar-90	CRO	HNGEL_CL	C	LIVER	475	1120	1	4	3			1.42	2.00		51.09	32.00			9.18	0.13	83.47		0.222
Mar-90	CRO	LIONS_CL	C	LIVER	506	1510	1	4	6			1.52	12.70		41.50	81.70			9.05	0.03	93.74		0.226
Mar-90	CRO	LIONS_CL	Om	LIVER	254	610	1	5	4			1.77	5.23		1466.61	20.20			143.32	7.40	159.75		0.306
Mar-90	CRO	MATAFFIN	C	LIVER	512	2800	1	5	2			0.50	1.29		16.43	25.60			14.06	0.70	66.62		0.178
Mar-90	CRO	RVERSIDE	Lc	LIVER	270.5	460	1	2.5				1.68	1.56		219.78	18.40			7.71	0.59	53.97		0.308
Mar-90	CRO	RVULETTS	C	LIVER	655	3200	2	5	4			1.15	2.13		32.46	19.00			7.54	1.03	63.77		0.209
Jun-90	CRO	HNGEL_CL	C	LIVER	417	840	2	1	1			1.42	4.21		76.08	4.98			7.89	1.02	275.25		0.300
Jun-90	CRO	LIONS_CL	C	LIVER	841	7250	1	3				3.53	13.69		79.63	15.13			9.90	2.19	240.62		0.250
Jun-90	CRO	RVERSIDE	Lr	LIVER	223.7	570	1	2.7				7.66	16.83		2195.06	1.95			208.67	6.15	135.79		0.220
Jun-90	CRO	RVERSIDE	Tr	LIVER	281.5	670	2	1				2.00	8.30		117.33	0.58			47.81	4.00	141.85		0.170
Jun-90	CRO	RVULETTS	Bm	LIVER	265	413.3	2	4	2.3			3.01	8.38		63.75	0.58			8.12	3.01	104.03		0.270
Jun-90	CRO	TENBOSCH	Hv	FLESH	286	300	2	1	1			0.68	2.33		1.80	0.03			3.50	0.62	25.29		0.230
Jun-90	CRO	TENBOSCH	Lc	LIVER	420	2500	2	3	3			5.81	9.32		310.70	0.67			19.37	3.04	105.07		0.210
Jun-90	CRO	TENBOSCH	Om	LIVER	261	775	1.7	3	4.7			4.69	9.90		22.01	1.08			40.10	5.12	91.98		0.200
Jun-90	CRO	TENBOSCH	Om	GUT	246	650	1	4	4			4.50	70.37		30.30	10.78			680.18	41.67	117.06		0.180
Jun-90	CRO	TENBOSCH	Tr	LIVER	255	900	1	4	5			2.01	7.51		644.35	0.17			9.29	2.55	113.31		0.260

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Oct-90	CRO	CROC_HOT	Bm	LIVER	334	1250	2	4.7	3			0.02	8.80		9.40	0.13			5.50	5.40	26.46		0.426
Oct-90	CRO	CROC_HOT	C	FAT	625	2675	1	4				0.02	8.80		0.80	0.05			1.90	5.60	2.97		0.971
Oct-90	CRO	HNGEL_CL	C	LIVER	491	1325	1.5	4				0.02	8.80		44.50	1.07			5.30	4.80	49.02		0.300
Oct-90	CRO	LIONS_CL	C	LIVER	477.5	1250	2	2.5	4			0.93	13.60		77.80	1.64			7.40	7.80	75.39		0.242
Oct-90	CRO	LIONS_CL	Lm	LIVER	287	666.7	1	4	0			0.44	14.80		150.30	0.21			19.10	7.40	64.51		0.259
Oct-90	CRO	RVERSIDE	Bm	LIVER	248	433.3	1.33	4	2			1.25	13.70		282.80	0.34			40.80	6.60	66.80		0.250
Oct-90	CRO	RVERSIDE	C	LIVER	580	2200	1	5	4			0.37	9.90		99.60	1.00			14.10	5.90	64.80		0.232
Oct-90	CRO	RVERSIDE	Lc	LIVER	263	575	2	5				0.80	7.20		214.70	0.43			25.90	4.20	37.38		0.316
Oct-90	CRO	RVULETTS	Bm	FAT	350	1100	2	2	2			0.02	5.60		0.40	0.05			2.00	5.00	2.48		0.992
Oct-90	CRO	RVULETTS	C	FAT	624	2725	1	4	4			0.02	7.90		0.70	0.06			1.10	5.10	4.02		0.932
Oct-90	CRO	RVULETTS	C	LIVER	602.5	2250	1	4				0.17	10.00		61.30	1.87			6.80	6.90	67.10		0.208
Oct-90	CRO	TENBOSCH	Lc	LIVER	482	2060	2	5	3			1.34	8.70		37.50	0.17			28.60	5.60	42.24		0.249
Oct-90	CRO	TENBOSCH	Om	LIVER	279	866	1.7	4	4			0.53	13.60		15.40	0.48			23.00	9.50	55.17		0.247
Oct-90	CRO	TENBOSCH	Tr	LIVER	285	1303.3	1	4.7				0.02	8.00		79.30	0.16			25.00	5.70	46.57		0.281
Jan-91	CRO	HNGEL_CL	Bm	LIVER	245	350	2	5	2.3			0.63	1.65		10.80	265.50			5.79	0.77	63.40		0.254
Jan-91	CRO	HNGEL_CL	C	LIVER	498	1410	1	4	2			0.83	1.59		15.40	861.70			4.13	0.06	62.30		0.239
Jan-91	CRO	TENBOSCH	Lc	LIVER	378	1350	1	5	5			1.98	1.63		587.10	226.50			5.35	0.28	107.20		0.217
Mar-91	CRO	CROC_HOT	Bm	LIVER	213.6	205	1	3	3			0.39	1.77		40.20	385.00			6.14	1.30	90.50		0.206
Mar-91	CRO	HNGEL_CL	C	LIVER	543	1700	2	2	4			0.65	1.64		43.60	2560.00			3.07	0.30	125.30		0.215
Mar-91	CRO	LIONS_CL	C	LIVER	545	2300	2	2	3			1.20	8.93		50.70	855.00			5.47	0.80	101.20		0.244
Mar-91	CRO	MATAFFIN	C	LIVER	413	980	2	2	2			0.22	1.34		52.40	1859.00			4.26	2.31	128.70		0.223
Mar-91	CRO	RVERSIDE	Bm	LIVER	323.5	1030	1.5	5				0.26	1.50		24.30	552.00			3.93	0.82	94.70		0.223
Mar-91	CRO	RVERSIDE	C	LIVER	450	1100	2	2	4			0.95	1.86		165.10	2398.00			3.81	0.91	284.50		0.209
Mar-91	CRO	RVERSIDE	Lc	LIVER	269	597.5	1	3				2.27	3.37		401.70	791.00			23.93	1.51	95.60		0.255
Mar-91	CRO	RVULETTS	C	LIVER	420		1	2	2			0.22	1.66		46.70	1104.00			3.05	0.09	147.20		0.218
Mar-91	CRO	TENBOSCH	Om	LIVER	283	930	2	4	5			2.05	2.40		538.50	1950.00			27.57	2.99	65.70		0.255
Mar-91	CRO	TENBOSCH	Tr	LIVER	319	750	1	2				0.20	0.92		21.50	750.00			2.25	0.32	47.90		0.416
Sep-91	CRO	CROC_HOT	Bm	LIVER	304.5	785	1.5	3.5				0.04	0.74		21.50	143.30			5.20	1.11	74.80		0.285
Sep-91	CRO	HNGEL_CL	C	LIVER	411	555	1.5	1.5				0.69	1.04		197.60	678.80			6.90	0.35	246.50		0.243
Sep-91	CRO	LIONS_CL	Bm	LIVER							2.54	0.03	1.02		23.40	131.40			27.40	0.76	42.70		0.375
Sep-91	CRO	LIONS_CL	C	LIVER	384.7	716.66	1.3	2.3				0.94	1.41		133.90	765.50			15.00	0.47	152.70		0.204
Sep-91	CRO	LIONS_CL	C	FAT	363	616	2	2				0.04	0.73		0.40	19.30			2.20	0.73	1.80		0.939
Sep-91	CRO	MATAFFIN	Bm	LIVER	267	490	1	5				0.04	0.73		23.00	108.00			5.10	0.36	71.20		0.270
Sep-91	CRO	RVERSIDE	Lc	LIVER	303.6	666.6	1	2			2.49	0.50	1.00		66.30	150.80			5.50	1.00	41.10		0.381
Sep-91	CRO	RVERSIDE	Lm	LIVER	295	635	1	4.5			3.09	1.86	1.86		414.60	182.50			15.50	0.93	115.10		0.299
Sep-91	CRO	RVERSIDE	Si	LIVER	254	242.5	2	2.5				0.44	1.32		28.90	632.50			6.60	0.88	118.00		0.227
Sep-91	CRO	TENBOSCH	Lc	LIVER	360.5	1250	2	2	3			3.66	1.83		625.20	393.10			4.10	0.46	134.40		0.219
Sep-91	CRO	TENBOSCH	Om	LIVER	294	940	1	5	5			0.99	0.99		36.20	465.70			10.20	1.98	59.90		0.246
Sep-91	CRO	TENBOSCH	Om	LIVER	275.5	900	2	3.5			3.88	1.55	1.16		8.20	280.70			11.30	1.94	69.90		0.245
Sep-91	CRO	TENBOSCH	Tr	LIVER	260.8	916	2	3.6				0.40	0.80		22.40	156.40			5.60	0.80	67.20		0.226
Sep-92	CRO	LIONS_CL	C	GILLS	420	1000	2	2		308.00	2.00	2.48	1.86		6.20	307.69			93.67	0.62	95.53		0.335

Date	River	Site	spp	Tissue	Length	Mass	Gender	Gl	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Sep-92	CRO	LIONS_CL	C	GILLS	415	750	2	4		106.00	2.00	1.75	1.31		11.78	134.38			150.96	0.44	125.22		0.385
Sep-92	CRO	LIONS_CL	C	LIVER	420	1000	2	2		33.00	2.00	2.12	1.06		97.46	1658.90			21.19	11.65	276.48		0.188
Sep-92	CRO	MATAFFIN	C	LIVER	640	3000	1	3		25.00	2.00	0.86	0.43		79.62	678.51			5.14	3.00	224.32		0.264
Sep-92	CRO	MATAFFIN	C	GILLS	620	3000	2	2		156.00	2.00	1.28	0.96		4.16	169.26			46.36	0.64	75.45		0.444
Sep-92	CRO	MATAFFIN	C	LIVER	620	3000	2	2		8.00	2.00	1.07	0.54		92.81	1019.31			8.05	5.90	290.77		0.255
Sep-92	CRO	RVULETTS	Bm	GILLS	465	2700	2	5		179.00	2.00	1.42	1.89		6.62	401.23			15.60	1.42	57.66		0.269
Sep-92	CRO	RVULETTS	Bm	LIVER	465	2700	2	5		36.00	2.00	1.11	0.56		8.35	351.34			3.90	3.34	77.39		0.286
Sep-92	CRO	TENBOSCH	Tr	GILLS	270	1134	1	5		89.00	2.00	1.63	1.08		4.88	174.08			55.31	27.66	473.97		0.260
Sep-92	CRO	TENBOSCH	Tr	LIVER	230	619	2	2		30.00	2.00	0.97	0.48		43.61	170.54			7.75	0.97	154.55		0.279
Sep-92	CRO	TENBOSCH	Tr	LIVER	270	1134	1	5		43.00	2.00	0.84	0.84		616.36	355.40			19.39	4.22	201.94		0.262
May-93	LET	HUDSON	C	LIVER	370	545	2	1	2	19.11		0.10	0.50		102.44	254.25			5.04		209.50		0.285
May-93	LET	HUDSON	Lr	GUT	225	320	2	2	2	9782.02		0.49	67.71	9.59	30.11	2128.98		3.41	341.46		54.02		0.409
May-93	LET	HUDSON	Lr	LIVER	233.25	345.75	2	1.5	2.25	579.38		1.55	5.67		990.72	507.06			8.71		147.99		0.277
May-93	LET	HUDSON	Om	GILLS	290	859	2	2	2.5	100.57		0.10	1.58		3.94	104.67			17.86		41.52		0.448
May-93	LET	HUDSON	Om	LIVER	285.5	850.5	2	3	3	57.41		0.59	0.50		28.94	87.25			1.40		35.13		0.605
May-93	LET	MIDLET	C	LIVER	483	1200	2	2	4	88.10		0.10	0.50		23.33	6273.00			3.81		134.10		0.283
May-93	LET	MIDLET	C	LIVER	650	6250	2	2	4	20.80		0.10	1.21		57.83	1973.28			7.00		127.37		0.335
May-93	LET	MIDLET	Lrd	LIVER	171.2	103.6	2	1	1.5	120.69		0.10	0.50		224.14	5545.96			19.07		166.38		0.235
May-93	LET	MIDLET	Om	GILLS	170	103	2	1	1	149.29		0.10	0.50		15.60	252.76			135.52		153.16		0.190
May-93	LET	MIDLET	Om	LIVER	161	89.9	2	1.2	1	179.28		1.15	0.50		2135.42	418.15			28.23		147.09		0.264
Feb-90	LET	JUNCTION	C	LIVER	398	650	1	2				0.92	2.14		85.47	37900.00			18.81	0.05	82.87		0.217
Feb-90	LET	JUNCTION	Om	LIVER	268	763.3	2	4.3				1.00	6.01		478.19	21600.00			35.31	4.48	82.40		0.261
Feb-90	LET	JUNCTION	Om	LIVER	264	720	1	4				0.65	1.03		411.54	10500.00			9.18	1.09	45.04		0.383
Feb-90	LET	SLAB	C	LIVER	463	1320	1	4				0.46	1.31		18.67	6900.00			6.45	0.16	33.91		0.274
May-90	LET	PRIESKA	Bm	LIVER	275	520	1	3.5				4.54	9.29		20.40	730.00			9.29	2.10	72.91		0.260
May-90	LET	PRIESKA	C	LIVER	430	860	1	2				2.88	6.46		45.62	8670.00			9.94	1.60	100.85		0.210
Aug-90	LET	JUNCTION	C	LIVER	628	2800	1	2	4			0.47	9.27		156.40	11312.80	6.96			3.58	188.20		0.253
Aug-90	LET	JUNCTION	Om	EGGS	262	680	2	5	4			0.05	6.38		9.80	45.70	0.65			3.16	143.00		0.466
Aug-90	LET	JUNCTION	Om	LIVER	252.2	645	2	3.5	3.75			0.42	7.59		191.30	396.30	3.20			3.44	95.10		0.269
Aug-90	LET	PRIESKA	Om	LIVER	223	435	1	4	2.3			0.20	10.73		232.60	2353.50	4.22			6.27	110.00		0.247
Aug-90	LET	PRIESKA	Si	LIVER	278	315	2	2.5				0.44	4.00		66.60	1476.80	2.36			1.16	157.10		0.238
Aug-90	LET	PUMP_STA	Bm	LIVER	214.3	246.7	1	3.3				0.27	6.40		395.70	711.10	4.47			2.15	155.90		0.233
Aug-90	LET	PUMP_STA	Bm	TESTES	254	340	1	6	2			0.20	14.10		4.50	47.70	1.07			7.64	105.90		0.215
Aug-90	LET	PUMP_STA	Om	LIVER	223	260	1	1	2.3			0.55	9.99		9.14	209.90	8.52			5.07	93.20		0.300
Aug-90	LET	PUMP_STA	Si	LIVER	272.5	300	2	3	2.5			0.35	6.40		79.30	2175.00	2.39			2.01	219.30		0.186
Aug-90	LET	SLAB	Om	LIVER	223	335	1.3	2	3.7			1.77	7.43		1731.70	183.90	7.88			4.59	103.70		0.258
Nov-90	LET	ENGLHRDT	Om	LIVER	201.3	226.7	1	3.7				1.03	2.11		258.40	861.20			10.77	0.63	72.00		0.227
Nov-90	LET	JUNCTION	Om	LIVER	284	1225	1	4.5				0.96	1.78		618.40	965.10			3.46	0.84	54.30		0.350
Nov-90	LET	PRIESKA	Lm	LIVER	234.3	146.67	2	5				1.76	1.52		600.00	173.70			14.67	0.09	193.90		0.228
Nov-90	LET	SLAB	Om	LIVER	205	250	1	2.3	1			0.80	0.89		531.20	177.20			9.26	0.93	84.30		0.213
Feb-91	LET	JUNCTION	Om	LIVER	262.5	760	2	4	4			0.94	1.28		555.60	954.00			6.75	1.42	65.20		0.316
Feb-91	LET	PRIESKA	Om	LIVER	175	160	1.67	2	1			1.07	1.25		431.60	2021.00			7.65	1.40	83.30		0.253

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Feb-91	LET	SLAB	C	LIVER	465	1600	1	3	4			0.26	0.49		13.70	186.00			2.00	4.00	32.10		0.589
May-91	LET	PRIESKA	Bm	TESTES	261	400	1	4				0.07	9.80		15.40	1355.00			26.60	4.90	49.70		0.259
Aug-91	LET	DRFT_ENG	Om	LIVER	189	240	1	3				0.29	1.17		514.00	246.20			8.70	2.04	56.80		0.295
Aug-91	LET	ENGLHRDT	C	LIVER	764	6250	1	5				0.37	1.12		82.20	655.50			3.00	0.37	123.70		0.241
Aug-91	LET	JUNCTION	Om	LIVER	245	920.5	1.5	3				1.29	4.83		1202.30	655.00			23.90	3.54	75.10		0.299
Aug-91	LET	PRIESKA	C	LIVER	620	3500	1	5				0.47	1.41		45.00	805.80			3.30	0.47	97.60		0.202
Aug-91	LET	PRIESKA	C	LIVER	517.5	1955	2	2.5				0.04	0.88		35.60	822.10			4.80	0.44	83.00		0.204
Aug-91	LET	PRIESKA	Om	LIVER	615	3250	1	4				0.04	0.76		94.90	588.90			5.30	0.76	63.90		0.251
Aug-91	LET	PRIESKA	Si	LIVER	276	345.6	2	2.7				0.46	2.31		55.40	638.80			3.70	0.46	102.90		0.217
Aug-91	LET	PUMP_STA	C	LIVER	403.5	730	1	2.5				0.04	1.23		65.00	608.10			4.90	0.41	104.00		0.248
Aug-91	LET	PUMP_STA	Om	LIVER	232.5	735	1	2.5				0.30	0.30		642.10	457.80			3.30	0.59	66.30		0.323
Aug-91	LET	SLAB	C	LIVER	508	1825	1	4				0.78	4.65		114.70	712.00			3.10	0.39	138.40		0.251
Aug-91	LET	SLAB	Lm	LIVER	236	376.6	2	1.5				0.30	0.60		176.40	111.80			5.10	0.60	58.90		0.342
Aug-91	LET	SLAB	Om	LIVER	232.7	522.7	1.7	4				0.35	1.05		523.50	248.20			3.90	1.40	69.30		0.283
Nov-91	LET	JUNCTION	C	LIVER	488	1406.7	1.7	5				0.04	0.77		28.40	778.80			6.10	0.38	80.10		0.242
Nov-91	LET	PRIESKA	C	FAT	415	1000	1	3				0.03	0.68		0.30	15 00				0.34	1.00		0.958
Nov-91	LET	PRIESKA	C	TESTES	625	2950	1	5				0.12	2.30		5.80	274.20			17.30	1.15	68.00		0.132
Nov-91	LET	PRIESKA	C	LIVER	645	3550	2	5				0.36	3.28		28.80	264.60			5.10	0.36	83.50		0.271
Nov-91	LET	PRIESKA	C	LIVER	425	1000	1.5	3.5				0.04	0.86		37.30	741.40			5.10	0.43	88.30		0.240
Nov-91	LET	PRIESKA	Om	LIVER	220	372	1	4				0.05	1.00		306.20	320.80			8.00	0.50	77.30		0.183
Nov-91	LET	PRIESKA	Si	LIVER	260	266.75	2	3.75				0.40	0.81		19.80	620.10			5.70	0.40	80.50		0.230
Nov-91	LET	PUMP_STA	Om	LIVER	257	682.5	1	2.5				0.35	1.06		984.80	507 40			20.20	1.77	64.00		0.297
Nov-91	LET	SLAB	C	LIVER	571	1850	1	4				0.89	0.89		36.00	261.80			2.40	0.30	53.70		0.294
Nov-91	LET	SLAB	Lm	LIVER	248	484	1.7	5				0.61	1.83		313.90	203.90			9.20	1.53	79.20		0.258
Nov-91	LET	SLAB	Om	FAT	252.5	692.25	1	5				0.04	1.20		0.80	47.60			1.20	0.80	2.00		0.815
Nov-91	LET	SLAB	Om	LIVER	252	668.6	1	5				0.30	0.60		974.30	249.10			5.40	0.91	70.40		0.276
Jun-92	LET	JUNCTION	Lr	LIVER	289	582.5	2	1	5	226.00		1.71	0.43		1405.98	1022.65			6.41		91.03		0.349
Jun-92	LET	JUNCTION	Om	LIVER	287	878	1	4	2	154 00		1.31	0.33		138.31	601.51			5 26		165.24		0.356
Jun-92	LET	PRIESKA	C	LIVER	510	1600	1	3	1	56.00		0 88	0.44		19.40	915.79			3.53		77.60		0.271
Jun-92	LET	PRIESKA	Om	LIVER	222	463.5	1.5	3.5	3.5	41.00		0.56	0.28		455.13	399.39			3.34		79.99		0.355
Jun-92	LET	PRIESKA	Om	LIVER	222	477	1	3	3	1330 00		1.11	4.42		8.11	614.68			39.09		81.12		0 335
Jun-92	LET	PRIESKA	Si	LIVER	234	182	2	1.75	1.5	31.00		1.44	0.48		50.48	743.27			6.73		112.98		0.274
Jun-92	LET	PUMP_STA	Lr	LIVER	300	827	2	1	4	125.00		1.07	2.14		263.55	794.58			6.06		82.03		0.345
Jun-92	LET	RANCH16	Lr	LIVER	244	381.7	1.3	1	3.7	135.00		2.43	0.61		1070.39	805.22			51.58		123.18		0.251
Jun-92	LET	RANCH16	Si	LIVER	276	329	2	3	3	74 00		1.92	0.64		57.55	997.44			7.03		143.22		0.244
Jun-92	LET	SLAB	C	LIVER	343	556	2	1	1	93.00		0.72	0.72		45.52	1333.09			8.67		135.12		0.250
Jun-92	LET	SLAB	Om	LIVER	215	393 5	2	2.5	2	56.00		0.55	1.66		681.42	686.95			8.85		91.81		0.322
Jun-92	LET	SLAB	Om	FLESH	215	393.5	2	2.5	2	44 00		0.39	0.39		5.81	161.77			2.32		6.58		0.946
Jul-93	LEV	FARM	Bm	LIVER	360	1000	2	3	2						18.08	570.35			13.28		63.43		0 295
Jul-93	LEV	FARM	Bm	GILLS	360	1000	2	3	2						4.02	745 73			26.35		63.26		0 260
Jul-93	LEV	FARM	Bm	EGGS	360	1000	2	3	2						8.32	179.36			3.69		161.89		0.236
Jul-93	LEV	FARM	Bm	LIVER	320	727	2	2	3						138.98	371.88			5.53		91.78		0.304

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Jul-93	LEV	FARM	Bm	GILLS	320	727	2	2	3						3.00	325.08			29.80		60.96		0.298
Jul-93	LEV	FARM	C	GILLS	430	900	1	6	3						5.49	136.51			27.66		326.18		0.264
Jul-93	LEV	FARM	C	LIVER	430	900	1	6	3						69.31	1748.03			5.33		126.30		0.284
Jul-93	LEV	FARM	Om	GILLS	240	548	1	2	4						13.87	213.68			133.31		50.56		0.294
Jul-93	LEV	MKYADNST	C	LIVER	485	1300	1	1	3						120.30	1757.43			4.46		381.72		0.299
Jul-93	LEV	MKYADNST	C	LIVER	430	1000	2	2							121.28	3018.20			7.87		359.34		0.248
Jul-93	LEV	MKYADNST	C	GILLS	430	1000	2	2							5.06	203.29			33.44		164.08		0.330
Jul-93	LEV	MKYADNST	Hv	LIVER	440	1720	2	4							71.29	2504.31			4.83		379.09		0.269
Jul-93	LEV	MKYADNST	Hv	GILLS	440	1720	2	4							2.50	87.32			17.55		99.26		0.348
Jul-93	LEV	MKYAUPST	C	LIVER	485	1165	1	2	4						120.34	3864.07			6.04		250.48		0.246
Jul-93	LEV	MKYAUPST	C	GILLS	435	876	2	1	5						5.26	1806.45			38.42		175.39		0.324
Jul-93	LEV	MKYAUPST	C	GILLS	485	1165	1	2	4						4.00	145.28			24.85		330.90		0.354
Jul-93	LEV	MKYAUPST	C	LIVER	435	876	2	1	5						155.93	3119.55			8.33		363.22		0.223
Jul-93	LEV	MKYAUPST	C	GILLS	550	1870	1	1	3						6.40	1379.78			30.78		114.44		0.388
Jul-93	LEV	MKYAUPST	C	LIVER	550	1870	1	1	3						65.54	1017.80			4.30		244.70		0.245
Jul-93	LEV	MKYAUPST	Lc	GILLS	295	766	2	1							4.52	511.04			29.08		110.52		0.303
Jul-93	LEV	MKYAUPST	Lc	GILLS	320	938	2	1							5.84	200.27			66.42		376.32		0.258
Jul-93	LEV	MKYAUPST	Lc	LIVER	320	938	2	1							215.06	332.30			56.68		342.82		0.319
Jul-93	LEV	SETTLMNT	C	LIVER	395	800	2	1	3						61.15	3046.18			6.44		268.52		0.282
Jul-93	LEV	SETTLMNT	Om	GILLS	210	365	1	3							5.58	765.24			63.59		210.28		0.293
Jul-93	LEV	SETTLMNT	Om	LIVER	200	309.5	1	2.5							348.26	1540.12			19.33		369.06		0.297
Jul-93	LEV	SETTLMNT	Om	GILLS	190	254	1	2							5.50	808.98			47.79		451.01		0.317
Aug-92	LEV	FARM	C	LIVER	370	590	2	2	2						80.02	750.42			3.32		108.62		0.268
Aug-92	LEV	FARM	C	GILLS	370	590	2	2	2						7.17	332.61			38.03		60.79		0.410
Aug-92	LEV	FARM	Unia	WHOLE											5.17	24.79			1820.8		146.69		0.294
Aug-92	LEV	MKYAUPST	C	LIVER	440	990	1.5	2.5	2						52.08	970.56			8.15		108.70		0.259
Aug-92	LEV	MKYAUPST	C	GILLS	450	1117	1	3	2						16.19	420.98			49.55		76.75		0.312
Aug-92	LEV	MKYAUPST	Lc	LIVER	311	934	1	1	2						1370.64	1014.75			12.06		349.87		0.278
Aug-92	LEV	MKYAUPST	Lc	LIVER	350	1348	2	2	2						2881.02	343.58			4.01		84.89		0.289
Aug-92	LEV	MKYAUPST	Lr	LIVER	305	855	2	1	2						866.60	604.61			7.20		168.91		0.287
Aug-92	LEV	MKYAUPST	Lr	GILLS	320	1196	2	1	2						8.99	440.65			64.75		238.85		0.300
Aug-92	LEV	SETTLMNT	Om	LIVER	175	242	1	2							318.09	430.92			10.93		63.62		0.323
Aug-92	LEV	SETTLMNT	Om	GILLS	175	242	1	2							5.03	347.19			58.98		55.63		0.315
Feb-93	OLI	ARABIE	C	LIVER	980	13000	2	4	4.5	13.39		0.05	1.73	1.34	23.16	2544.64		0.60	5.04		93.67		0.284
Feb-93	OLI	ARABIE	C	LIVER	476	1230	2	4		91.26		0.05	3.04	2.27	51.33	2635.51		0.60	5.20		101.94		0.230
Feb-93	OLI	ARABIE	C	LIVER	980	12000	2	5	5	21.37		0.48	2.30	2.70	16.41	3971.77		0.60	5.89		69.15		0.280
Feb-93	OLI	ARABIE	Cc	LIVER	640	6000	2	5		40.98		0.37	1.75	2.05	222.35	1719.45		0.60	7.41		242.59		0.228
Feb-93	OLI	ARABIE	Lr	LIVER	295	674	2	5		1056.64		0.34	2.98	2.69	26.17	4765.63		30.32	57.32		272.51		0.224
Feb-93	OLI	ARABIE	Lr	LIVER	270	446	1	4		355.56		4.79	4.49	3.38	29.79	4512.82		879.10	11.32		776.07		0.253
Feb-93	OLI	ARABIE	Om	GILLS	280	933	1	4	4	638.80		0.05	1.65	2.14	27.64	583.20		0.60	104.82		58.20		0.341
Feb-93	OLI	ARABIE	Om	LIVER	280	933	1	4	4	85.07		0.95	1.50	4.40	1254.99	1612.78		0.60	11.64		78.13		0.373
Feb-93	OLI	ARABIE	Om	LIVER	260	786	1	3		145.72		0.56	1.12	6.78	1001.25	417.76		0.60	13.36		46.48		0.368

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Feb-93	OLI	ARABIE	Om	LIVER	264	774	1	5		50.11		0.48	1.42	4.95	957.47	1059.46		0.60	7.59		50.34		0.345
Feb-93	OLI	ARABIE	Om	GILLS	234	572	2	5		357.95		0.05	1.76	0.94	22.71	411.92		0.60	57.98		76.99		0.273
Jun-93	OLI	BALULI	C	LIVER	715	2765	1	2		78.40		0.10	1.48	1.75	78.63	2262.60		0.40	4.99		160.12		0.335
Jun-93	OLI	BALULI	C	LIVER	205	83	1	1		47.56		0.99	0.50	0.10	60.88	3404.38		0.40	3.35		141.32		0.277
Jun-93	OLI	BALULI	C	GILLS	420	725	2	4		123.01		0.10	2.65	0.10	3.98	193.20		0.40	24.67		119.93		0.395
Jun-93	OLI	BALULI	C	GILLS	715	2765	1	2		126.12		0.10	2.99	0.10	4.85	245.15		0.40	26.53		118.32		0.319
Jun-93	OLI	BALULI	C	GILLS	205	83	1	1		683.75		0.10	5.00	0.10	8.13	644.56		0.40	45.44		150.25		0.218
Jun-93	OLI	MAMBA_WR	C	GILLS	570	2700	1	2	6	265.86		0.10	3.34	0.10	5.43	244.70		0.40	22.87		120.70		0.283
Jun-93	OLI	MAMBA_WR	C	LIVER	570	2700	1	2	6	7.78		0.10	0.50	0.10	20.24	298.04		0.40	1.85		72.38		0.363
Jun-93	OLI	MAMBA_WR	C	LIVER	497	1300	1	4	4	99.08		0.92	0.50	2.17	57.88	2154.19		0.40	2.98		160.62		0.322
Jun-93	OLI	MAMBA_WR	C	LIVER	565	2200	2	6		91.70		1.30	0.50	1.73	68.77	2128.84		0.40	2.45		127.39		0.309
Jun-93	OLI	MAMBA_WR	Lc	GILLS	330	937	2	2		174.70		0.10	0.50	1.14	13.13	347.59		0.40	48.80		510.60		0.246
Jun-93	OLI	MAMBA_WR	Lc	GILLS	310	762	2	2	2	376.11		0.10	0.50	1.67	15.28	379.72		0.40	40.61		457.33		0.237
Jun-93	OLI	MAMBA_WR	Lc	LIVER	330	937	2	2		448.78		3.35	3.49	1.14	978.46	1193.42		0.40	6.64		88.42		0.353
Jun-93	OLI	MAMBA_WR	Lc	LIVER	325	857	1	2	3	43.34		0.82	0.50	0.53	261.62	205.75		0.40	2.83		72.86		0.393
Jun-93	OLI	MAMBA_WR	Lc	LIVER	310	762	2	2	2	205.59		7.66	3.62	1.41	600.66	426.97		0.40	5.00		96.97		0.335
Jun-93	OLI	MAMBA_WR	Lc	LIVER	310	780	2	2	2	128.27		10.87	4.16	1.90	191.15	698.34		0.40	5.34		128.62		0.292
Jun-93	OLI	MAMBA_WR	Lc	LIVER	335	792	2	2	2	165.03		7.20	3.16	1.93	875.00	538.62		0.40	4.74		111.31		0.299
Jun-93	OLI	SELATI	C	LIVER	635	1511	2	2		99.61		1.56	0.50	0.94	92.89	1566.52		0.40	5.35		159.53		0.274
Jun-93	OLI	SELATI	Lrd	GILLS	230	328	2	1	3	112.61		0.10	0.50	1.43	32.09	261.17		0.40	142.87		337.22		0.253
Jun-93	OLI	SELATI	Lrd	LIVER	260	452	2	6	3	7.71		0.49	0.50	0.10	3662.54	111.93		0.40	6.70		107.87		0.298
Jun-93	OLI	SELATI	Lrd	LIVER	230	328	2	1	3	21.91		0.69	0.50	0.69	1700.47	184.62		0.40	7.82		137.67		0.275
Jun-93	OLI	SELATI	Lrd	GILLS	215	270	2	1		310.93		0.10	5.03	0.10	17.90	416.33		0.40	67.96		509.80		0.244
Jun-93	OLI	SELATI	Lrd	GILLS	260	452	2	6	3	42.47		0.51	5.42	0.10	4.99	126.82		0.40	47.43		255.76		0.340
Jun-93	OLI	SELATI	Lrd	LIVER	215	270	2	1		17.07		0.10	4.88	0.10	1903.66	208.72		0.40	7.68		200.98		0.319
Jun-93	OLI	SELATI	Om	LIVER	192	272	1	1	2	33.46		0.10	0.50	12.40	6802.10	1657.41		4.86	6.76		80.51		0.288
Jun-93	OLI	SELATI	Om	GILLS	189	251	2	6	1	109.69		0.10	0.50	0.79	54.35	200.99		8.03	21.98		58.15		0.296
Jun-93	OLI	SELATI	Om	GILLS	192	272	1	1	1	60.87		0.10	0.50	1.14	30.83	229.56		2.54	24.61		75.75		0.279
Jun-93	OLI	SELATI	Om	LIVER	189	251	2	6	2	34.18		0.10	0.50	10.91	5872.36	976.40		0.40	7.21		84.27		0.290
Jun-91	OLI	BALULI	C	TESTES	586	1391	1			10.00		0.51	0.30	3.58		82.89			28.37		51.08		0.248
Aug-91	OLI	MAMBA_WR	C	FAT						30.00		0.76	5.55	1.69		115.77			0.06		8.82		0.895
Aug-91	OLI	VYEBOOM	C	EGGS	523	1280	2			40.00		0.86	1.22	6.15		195.38			3.86		175.30		0.300
Feb-92	OLI	BALULI	C	LIVER	586	1391	1			160.00		1.21	0.88	49.54		433.04			5.81		153.35		0.255
Feb-92	OLI	BALULI	C	TESTES	894	5505	1			1080.00		1.02	5.48	5.02		917.78			11.07		250.67		0.216
Feb-92	OLI	BALULI	C	LIVER	442	725	2			50.00		0.93	0.80	35.97		514.03			6.46		135.88		0.290
Feb-92	OLI	SELATI	C	LIVER	672	2500	2			20.00		0.83	0.76	43.21		782.10			7.14		111.07		0.303
Jun-92	OLI	PRESELAT	C	LIVER	600	2800	2	1	3	677.00			1.62		103.90	1049.76		0.54	11.36		127.17		0.297
Jun-92	OLI	PSTSELAT	Bm	LIVER	352	1075	2	2	1	152.00			1.34		86.90	790.78		0.67	6.68		127.67		0.274
Jun-92	OLI	PSTSELAT	C	GILLS	580	2200	1	1	4	462.00			3.96		7.91	366.55		0.36	63.31		78.06		0.318
Jun-92	OLI	PSTSELAT	C	LIVER	510	2000	1	3	2	45.00			0.38		19.20	643.07		0.38	6.40		62.50		0.304
Jun-92	OLI	PSTSELAT	C	LIVER	775	5600	1	4	3	797.00			4.57		52.56	893.05		0.46	12.34		107.40		0.272

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Jun-92	OLI	PSTSELAT	C	LIVER	760	5250	1	3	2	106.00			0.51		125.00	975.92		0.51	6.66		138.83		0.303
Jun-92	OLI	PSTSELAT	C	LIVER	705	4500	2	1	3	45.00			0.40		76.83	751.99		1.99	3.98		94.35		0.289
Jun-92	OLI	PSTSELAT	Lc	GILLS	305	805	1	1	3	503.00			3.99		12.97	526.45		0.50	59.88		192.12		0.285
Jun-92	OLI	PSTSELAT	Lc	LIVER	320	975	2	2	3	496.00			2.78		1938.89	718.89		11.67	10.56		256.11		0.321
Jun-92	OLI	PSTSELAT	Om	LIVER	173	223.5	2	2	3	239.00			1.43		2051.53	496.18		61.07	9.54		406.01		0.306
Feb-93	OLI	KLIPSPRT	Bm	LIVER	272.5	500	2	5	4	166.86			1.84	2.20	28.74	539.01		4.28	14.85		233.14		0.253
Feb-93	OLI	KLIPSPRT	C	GILLS	550	1700	2	2	4	279.04			2.62	5.45	5.31	436.19		0.60	26.91		155.24		0.158
Feb-93	OLI	KLIPSPRT	C	TESTES	385	606	1	2	2	236.32			1.70	3.02	5.61	258.02		15.42	73.11		233.54		0.211
Feb-93	OLI	KLIPSPRT	C	EGGS	550	1700	2	2	4	132.43			0.76	3.14	4.07	872.58		0.60	0.04		241.94		0.165
Feb-93	OLI	KLIPSPRT	C	LIVER	535	1600	1	2	3	212.12			1.23	6.91	26.85	1190.81		0.60	1.42		143.70		0.220
Feb-93	OLI	KLIPSPRT	C	LIVER	550	1700	2	2	4	311.12			1.76	4.35	25.22	1275.06		0.60	0.06		160.08		0.222
Feb-93	OLI	KLIPSPRT	C	GILLS	475	1700	1	2	3	166.04			2.84	5.49	5.37	309.34		0.60	42.93		114.58		0.168
Feb-93	OLI	KLIPSPRT	C	LIVER	385	606	1	2	2	72.46			1.05	4.54	14.93	695.52		0.60	2.77		174.61		0.178
Feb-93	OLI	KLIPSPRT	C	GILLS	535	1600	1	2	3	304.56			3.17	6.55	7.34	312.50		22.12	14.88		428.27		0.145
Feb-93	OLI	KLIPSPRT	C	GILLS	475	1700	1	2	3	561.68			3.08	6.89	7.22	385.83		0.60	53.15		144.29		0.171
Feb-93	OLI	KLIPSPRT	C	LIVER	413	792	2	4		36.38			1.06	3.64	8.80	760.71		4.83	0.07		223.48		0.200
Feb-93	OLI	KLIPSPRT	C	LIVER	530	1800	1	2	3	132.17			0.84	4.70	28.26	850.84		3.50	2.39		166.48		0.211
Feb-93	OLI	KLIPSPRT	C	GILLS	535	1600	1	2	3	242.09			1.82	5.41	5.78	326.64		0.60	35.28		157.97		0.169
Jun-93	SAB	WEIR	Bm	LIVER	392	1700	2	2		64.06		0.99				1688.18			9.74		95.06		0.231
Jun-93	SAB	WEIR	Bm	LIVER	287	550	1	1		85.64		0.59				457.34			9.89		113.14		0.240
Jun-93	SAB	WEIR	Bm	LIVER	303	750	1	2		53.84		0.10				278.36			7.84		99.41		0.244
Jun-93	SAB	WEIR	Bm	GILLS	392	1700	2	2		441.65		0.10				1056.28			30.70		88.78		0.238
Jun-93	SAB	WEIR	Bm	LIVER	310	1000	2	1		60.93		0.63				291.20			8.03		107.50		0.237
Jun-93	SAB	WEIR	Bm	LIVER	366	1250	2	2		32.84		0.85				1059.32			6.46		130.72		0.218
Jun-93	SAB	WEIR	C	GILLS	690	3750	2	2		104.73		0.10				187.73			47.66		112.79		0.342
Jun-93	SAB	WEIR	C	LIVER	690	3750	2	2		106.04		2.83				4175.55			5.17		177.57		0.248
Jun-93	SAB	WEIR	C	LIVER	550	1900	1	2		20.83		0.10				3517.75			3.85		123.73		0.249
Jun-93	SAB	WEIR	Hv	LIVER	350	860	2	2		38.14		0.10				1506.39			6.19		118.71		0.263
Jun-93	SAB	WEIR	Hv	LIVER	312	605	2	2		7.83		0.10				3198.98			5.66		154.22		0.255
Jun-93	SAB	WEIR	Lc	LIVER	290	809	2	2		174.22		0.74				277.88			9.18		67.09		0.345
Jun-93	SAB	WEIR	Lc	GILLS	314	903	2	2		150.65		0.56				298.88			51.73		285.73		0.248
Jun-93	SAB	WEIR	Lc	LIVER	304	855	2	2		85.04		0.47				266.30			4.96		43.07		0.362
Jun-93	SAB	WEIR	Lc	LIVER	312	833	1	1		25.29		0.59				254.99			3.85		48.24		0.352
Jun-93	SAB	WEIR	Lc	GILLS	290	809	2	2		90.76		0.50				185.29			49.92		262.18		0.287
Jun-93	SAB	WEIR	Lc	LIVER	314	903	2	2		52.35		0.91				244.50			3.26		38.47		0.429
Jun-93	SAB	WEIR	Lr	LIVER	314	1026	2	2		113.31		1.42				394.97			9.65		136.13		0.240
Jun-93	SAB	WEIR	Lr	LIVER	304	932	2	2		12.09		1.76				334.62			4.89		91.81		0.242
Jun-93	SAB	WEIR	Lr	LIVER	328	1211	2	2		24.83		0.52				357.76			3.81		79.65		0.310
Jun-93	SAB	WEIR	Lr	LIVER	342	1100	2	1		312.36		3.26				330.68			10.60		138.02		0.237
Jun-93	SAB	WEIR	Lr	LIVER	300	770	2	2		59.62		1.92				301.92			7.16		105.00		0.249
Jun-93	SAB	WEIR	Om	LIVER	275	822	1	2		224.22		0.67				2057.77			16.91		48.16		0.344

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	Al	As	Cd	Cr	Co	Cu	Fe	Mg	Pb	Mn	Ni	Zn	Hg	dwf
Jun-93	SAB	WEIR	Om	LIVER	240	581	1	3		24.96		0.10				1681.70			14.05		65.76		0.324
Jun-93	SAB	WEIR	Si	LIVER	310	502	2	3		9.80		0.76				1939.16			4.90		123.80		0.214
May-92	SAB	WEIR	Bm	LIVER	308	753	1	2	3	5.00		1.33				538.56			5.32				0.277
May-92	SAB	WEIR	C	LIVER	435	1078	2	4		111.00		0.92				920.81			8.75				0.251
May-92	SAB	WEIR	Lc	LIVER	330	1073	-1	1	2	9.00		1.05				282.12			2.10				0.413
May-92	SAB	WEIR	Lc	LIVER	333	1282	2	2	4	138.00		0.60				257.75			5.07				0.530
May-92	SAB	WEIR	Lr	LIVER	289	699	2	2	4	12.00		1.09				171.49			5.43				0.388
May-92	SAB	WEIR	Lr	LIVER	316	1027	2	4		80.00		1.18				405.81			6.28				0.305
May-92	SAB	WEIR	Si	LIVER	282	357	2	3	1	115.00		0.69				555.00			12.43				0.245
May-92	SAB	WEIR	Si	LIVER	285	380	2	2.5	4	11.00		1.04				974.53			5.20				0.230

Appendix C1: The number, mean, standard deviation and range of the metal loads detected per tissue for all the fish sampled.

		Liver		Gills		Eggs		Fat	
Al	n	116		41		3		1	
	Mean±Sd	124.700 ±	199.875	209.476 ±	172.715	76.051 ±	49.453	30.000 ±	0.000
	Range	5.000 -	1330.000	12.208 -	683.750	40.000 -	132.428	30.000 -	30.000
As	n	19		8		1		0	
	Mean±Sd	2.536 ±	1.362	1.822 ±	0.880	6.489 ±	0.000		
	Range	0.364 -	5.770	0.300 -	3.309	6.489 -	6.489		
Cd	n	234		36		17		14	
	Mean±Sd	1.023 ±	1.350	0.543 ±	0.589	0.149 ±	0.335	0.096 ±	0.196
	Range	0.015 -	10.870	0.050 -	2.481	0.015 -	1.183	0.015 -	0.760
Cr	n	198		25		17		14	
	Mean±Sd	3.099 ±	3.425	2.253 ±	1.560	1.049 ±	1.489	2.519 ±	3.076
	Range	0.025 -	16.830	0.500 -	5.416	0.025 -	6.380	0.202 -	8.800
Co	n	44		16		4		4	
	Mean±Sd	5.153 ±	10.781	1.796 ±	2.339	2.483 ±	2.783	0.663 ±	0.685
	Range	0.100 -	49.540	0.100 -	6.890	0.320 -	6.150	0.320 -	1.690
Cu	n	234		54		18		13	
	Mean±Sd	335.808 ±	758.880	9.206 ±	9.295	5.822 ±	2.256	0.685 ±	0.402
	Range	3.130 -	6802.100	2.503 -	54.346	2.490 -	10.280	0.280 -	1.485
Fe	n	245		46		25		14	
	Mean±Sd	1502.116 ±	3417.108	401.625 ±	330.758	197.423 ±	176.934	59.082 ±	78.095
	Range	0.130 -	37900.000	87.315 -	1806.452	45.700 -	872.581	0.050 -	275.000
Mg	n	8		0		1		0	
	Mean±Sd	5.000 ±	2.462			0.650 ±	0.000		
	Range	2.360 -	8.520			0.650 -	0.650		
Pb	n	70		30		4		3	
	Mean±Sd	14.760 ±	105.119	1.538 ±	4.137	0.560 ±	0.107	0.620 ±	0.000
	Range	0.377 -	879.100	0.360 -	22.123	0.400 -	0.620	0.620 -	0.620
Mn	n	258		58		18		13	
	Mean±Sd	11.268 ±	17.690	51.566 ±	38.248	5.459 ±	4.677	2.203 ±	2.330
	Range	0.055 -	208.670	4.034 -	161.561	0.042 -	18.244	0.060 -	7.760
Ni	n	138		5		15		13	
	Mean±Sd	2.066 ±	2.105	6.154 ±	12.027	1.092 ±	0.651	1.963 ±	1.923
	Range	0.030 -	11.650	0.436 -	27.657	0.473 -	3.160	0.340 -	5.600
Zn	n	258		58		26		14	
	Mean±Sd	122.220 ±	83.495	178.645 ±	140.823	144.565 ±	72.792	3.911 ±	2.342
	Range	25.413 -	776.070	41.520 -	510.602	65.920 -	409.247	1.000 -	8.820
Hg	n	8		3		1		0	
	Mean±Sd	0.069 ±	0.043	0.021 ±	0.028	0.007 ±	0.000		
	Range	0.020 -	0.120	0.003 -	0.053	0.007 -	0.007		
DWF	n	241		58		12		7	
	Mean±Sd	0.281 ±	0.066	0.299 ±	0.066	0.345 ±	0.085	0.929 ±	0.059
	Range	0.170 -	0.610	0.145 -	0.448	0.165 -	0.466	0.815 -	0.992

Appendix C1: cont.

		Flesh		Testes		Gut	
Al	n	1		3		1	
	Mean±Sd	44.000 ±	0.000	442.107 ±	563.903	9782.016 ±	0.000
	Range	44.000 -	44.000	10.000 -	1080.000	9782.016 -	9782.016
Cd	n	45		12		2	
	Mean±Sd	0.130 ±	0.125	0.201 ±	0.294	2.495 ±	2.835
	Range	0.015 -	0.680	0.015 -	1.020	0.490 -	4.500
Cr	n	45		13		2	
	Mean±Sd	1.177 ±	0.748	3.436 ±	4.115	69.041 ±	1.880
	Range	0.040 -	3.380	0.300 -	14.100	67.711 -	70.370
Co	n	11		4		1	
	Mean±Sd	0.320 ±	0.000	2.985 ±	1.966	9.591 ±	0.000
	Range	0.320 -	0.320	0.320 -	5.020	9.591 -	9.591
Cu	n	45		11		2	
	Mean±Sd	2.041 ±	1.042	7.019 ±	3.953	30.204 ±	0.135
	Range	0.585 -	5.805	2.160 -	15.400	30.109 -	30.300
Fe	n	45		14		2	
	Mean±Sd	53.693 ±	40.265	282.440 ±	379.256	1069.879 ±	1497.792
	Range	0.030 -	161.765	44.600 -	1355.000	10.780 -	2128.978
Mg	n	0		1		0	
	Mean±Sd			1.070 ±	0.000		
	Range			1.070 -	1.070		
Pb	n	11		2		1	
	Mean±Sd	0.620 ±	0.000	8.022 ±	10.468	3.406 ±	0.000
	Range	0.620 -	0.620	0.620 -	15.425	3.406 -	3.406
Mn	n	45		12		2	
	Mean±Sd	3.161 ±	3.135	21.637 ±	18.843	510.819 ±	239.513
	Range	0.330 -	17.150	1.360 -	73.113	341.458 -	680.180
Ni	n	44		10		1	
	Mean±Sd	0.784 ±	0.382	2.840 ±	2.078	41.670 ±	0.000
	Range	0.190 -	1.490	1.150 -	7.640	41.670 -	41.670
Zn	n	45		14		2	
	Mean±Sd	20.424 ±	9.487	103.533 ±	61.547	85.540 ±	44.577
	Range	4.495 -	61.823	49.700 -	250.670	54.019 -	117.060
DWF	n	18		7		2	
	Mean±Sd	0.251 ±	0.175	0.222 ±	0.046	0.294 ±	0.162
	Range	0.180 -	0.946	0.132 -	0.270	0.180 -	0.409

Appendix C2: The number, mean, standard deviation and range of the metal loads detected per species for all the rivers sampled

		O.mossambicus		*C.carpio*		*M.salmoides*		*M.dolomieu*		*C.gariepinus*		*S.intermedius*	
Al	n	41		10		2		2		53		5	
	Mean±Sd	142.371 ±	222.595	107.847 ±	194.803	89.230 ±	92.128	12.211 ±	0.004	173.828 ±	220.670	48.161 ±	45.502
	Range	24.964 -	1330.000	16.384 -	655.556	24.086 -	154.374	12.208 -	12.214	7.785 -	1080.000	9.804 -	115.000
As	n	10		4		0		0		6		0	
	Mean±Sd	3.154 ±	2.288	1.895 ±	0.907					2.000 ±	0.000		
	Range	0.300 -	6.490	0.963 -	3.139					2.000 -	2.000		
Cd	n	80		10		2		2		113		12	
	Mean±Sd	0.738 ±	0.888	0.852 ±	0.731	0.500 ±	0.000	0.365 ±	0.192	0.581 ±	0.677	0.683 ±	0.541
	Range	0.015 -	4.690	0.297 -	2.711	0.500 -	0.500	0.229 -	0.500	0.015 -	3.530	0.125 -	1.918
Cr	n	59		0		0		0		127		9	
	Mean±Sd	3.576 ±	9.327							2.611 ±	2.984	2.520 ±	2.032
	Range	0.180 -	70.370							0.040 -	13.900	0.481 -	6.400
Co	n	13		0		0		0		45		2	
	Mean±Sd	3.518 ±	4.180							4.954 ±	10.594	0.320 ±	0.000
	Range	0.320 -	12.400							0.100 -	49.540	0.320 -	0.320
Cu	n	85		10		2		2		136		9	
	Mean±Sd	438.077 ±	1033.761	89.712 ±	88.931	8.676 ±	8.638	4.604 ±	2.084	40.862 ±	42.852	45.251 ±	23.949
	Range	0.280 -	6802.100	3.907 -	297.210	2.569 -	14.784	3.130 -	6.077	0.300 -	197.600	3.109 -	79.300
Fe	n	67		0		0		0		151		12	
	Mean±Sd	1083.177 ±	2886.609							1577.676 ±	3868.128	1054.632 ±	643.203
	Range	0.480 -	21600.000							0.050 -	37900.000	109.620 -	2175.000
Mg	n	5		0		0		0		1		2	
	Mean±Sd	4.894 ±	3.294							6.960 ±	0.000	2.375 ±	0.021
	Range	0.650 -	8.520							6.960 -	6.960	2.360 -	2.390
Pb	n	34		10		2		2		44		2	
	Mean±Sd	2.723 ±	10.417	0.520 ±	0.103	0.600 ±	0.000	0.600 ±	0.000	1.563 ±	3.950	0.620 ±	0.000
	Range	0.400 -	61.070	0.400 -	0.600	0.600 -	0.600	0.600 -	0.600	0.360 -	22.120	0.620 -	0.620
Mn	n	82		10		2		2		145		10	
	Mean±Sd	28.774 ±	78.298	48.841 ±	62.840	11.743 ±	2.923	5.700 ±	2.356	12.435 ±	18.834	6.786 ±	2.381
	Range	0.850 -	680.180	3.079 -	161.561	9.676 -	13.810	4.034 -	7.366	0.042 -	150.960	3.700 -	12.431
Ni	n	40		0		0		0		84		7	
	Mean±Sd	3.391 ±	6.542							1.515 ±	1.979	0.994 ±	0.559
	Range	0.473 -	41.670							0.030 -	11.650	0.400 -	2.010
Zn	n	87		10		2		2		150		10	
	Mean±Sd	88.330 ±	70.118	268.827 ±	101.318	85.996 ±	42.239	72.783 ±	33.309	120.380 ±	84.257	120.165 ±	47.603
	Range	2.000 -	451.010	142.649 -	401.591	56.129 -	115.864	49.230 -	96.336	1.000 -	428.270	39.709 -	219.300
Hg	n	8		4		0		0		0		0	
	Mean±Sd	0.038 ±	0.040	0.081 ±	0.044								
	Range	0.003 -	0.110	0.032 -	0.120								
DWF	n	78		10		2		2		122		10	
	Mean±Sd	0.327 ±	0.117	0.300 ±	0.076	0.315 ±	0.062	0.321 ±	0.081	0.291 ±	0.150	0.231 ±	0.023
	Range	0.180 -	0.950	0.227 -	0.433	0.271 -	0.358	0.264 -	0.378	0.132 -	0.970	0.186 -	0.274

Appendix C2: cont.

		B.marequensis		*L.molybdinus*		*H.vittatus*		*T.rendalli*		*L.congoro*	
Al	n	11		0		2		3		17	
	Mean±Sd	116.165 ±	122.497			22.988 ±	21.435	54.000 ±	31.000	192.125 ±	162.741
	Range	5.000 -	441.652			7.831 -	38.144	30.000 -	89.000	9.000 -	503.000
As	n	3		1		0		3		1	
	Mean±Sd	2.180 ±	0.312	3.090 ±	0.000			2.000 ±	0.000	2.490 ±	0.000
	Range	2.000 -	2.540	3.090 -	3.090			2.000 -	2.000	2.490 -	2.490
Cd	n	51		18		5		19		25	
	Mean±Sd	0.447 ±	0.801	0.616 ±	0.908	0.226 ±	0.254	0.540 ±	0.691	2.160 ±	2.811
	Range	0.015 -	4.540	0.015 -	2.787	0.100 -	0.680	0.015 -	2.010	0.100 -	10.867
Cr	n	46		18		3		19		19	
	Mean±Sd	2.776 ±	3.467	2.251 ±	3.417	2.970 ±	1.690	2.196 ±	2.768	3.130 ±	2.670
	Range	0.025 -	14.100	0.260 -	14.800	1.693 -	4.886	0.120 -	8.300	0.500 -	9.320
Co	n	5		2		2		0		7	
	Mean±Sd	0.695 ±	0.840	0.320 ±	0.000	0.320 ±	0.000			1.389 ±	0.498
	Range	0.320 -	2.197	0.320 -	0.320	0.320 -	0.320			0.534 -	1.931
Cu	n	51		18		5		19		24	
	Mean±Sd	35.396 ±	86.988	262.953 ±	496.291	28.604 ±	35.810	112.563 ±	195.353	492.925 ±	705.141
	Range	0.400 -	408.350	1.400 -	2064.122	1.800 -	71.293	0.310 -	644.350	1.400 -	2881.016
Fe	n	60		19		7		20		32	
	Mean±Sd	344.878 ±	434.510	195.613 ±	193.068	1772.439 ±	1918.839	176.712 ±	221.488	348.044 ±	287.779
	Range	0.050 -	2299.400	0.210 -	738.200	0.030 -	5029.320	0.160 -	750.000	0.170 -	1193.423
Mg	n	2		0		0		0		0	
	Mean±Sd	2.770 ±	2.404								
	Range	1.070 -	4.470								
Pb	n	6		2		2		0		9	
	Mean±Sd	1.237 ±	1.489	0.620 ±	0.000	0.620 ±	0.000			1.663 ±	3.752
	Range	0.620 -	4.276	0.620 -	0.620	0.620 -	0.620			0.400 -	11.667
Mn	n	56		18		7		19		32	
	Mean±Sd	9.206 ±	9.037	12.687 ±	12.702	9.018 ±	5.670	12.586 ±	15.708	19.018 ±	20.345
	Range	0.418 -	40.800	1.310 -	41.020	3.500 -	17.548	0.610 -	55.315	2.095 -	66.423
Ni	n	44		18		3		19		10	
	Mean±Sd	1.796 ±	1.684	1.455 ±	1.565	1.140 ±	0.505	3.163 ±	6.133	1.750 ±	1.884
	Range	0.190 -	7.640	0.090 -	7.400	0.620 -	1.629	0.250 -	27.657	0.200 -	5.600
Zn	n	59		19		7		20		30	
	Mean±Sd	80.001 ±	66.031	90.080 ±	71.931	134.171 ±	120.686	101.063 ±	103.625	152.647 ±	137.037
	Range	2.480 -	409.247	12.680 -	212.800	17.669 -	379.095	5.870 -	473.970	19.290 -	510.602
DWF	n	41		7		5		13		32	
	Mean±Sd	0.278 ±	0.124	0.287 ±	0.061	0.273 ±	0.045	0.274 ±	0.070	0.303 ±	0.075
	Range	0.200 -	0.997	0.228 -	0.390	0.230 -	0.348	0.170 -	0.420	0.190 -	0.530

Appendix C2: cont.

		L.rosae		*L.ruddi*		*H.molitrix*	
Al	n	14		7		1	
	Mean±Sd	919.557 ±	2566.567	90.485 ±	107.429	40.984 ±	0.000
	Range	12.000 -	9782.016	7.711 -	310.930	40.984 -	40.984
Cd	n	15		7		1	
	Mean±Sd	2.079 ±	1.922	0.298 ±	0.255	0.373 ±	0.000
	Range	0.342 -	7.660	0.100 -	0.687	0.373 -	0.373
Cr	n	8		7		1	
	Mean±Sd	12.606 ±	22.875	2.474 ±	2.467	1.751 ±	0.000
	Range	0.427 -	67.711	0.500 -	5.416	1.751 -	1.751
Co	n	3		6		1	
	Mean±Sd	5.218 ±	3.803	0.420 ±	0.550	2.049 ±	0.000
	Range	2.686 -	9.591	0.100 -	1.435	2.049 -	2.049
Cu	n	10		7		1	
	Mean±Sd	688.737 ±	745.488	1077.970 ±	1405.181	222.355 ±	0.000
	Range	8.993 -	2195.060	4.989 -	3662.541	222.355 -	222.355
Fe	n	17		7		1	
	Mean±Sd	1051.846 ±	1430.335	979.366 ±	2016.241	1719.449 ±	0.000
	Range	1.950 -	4765.625	111.932 -	5545.959	1719.449 -	1719.449
Pb	n	3		6		1	
	Mean±Sd	304.277 ±	497.995	0.400 ±	0.000	0.600 ±	0.000
	Range	3.406 -	879.103	0.400 -	0.400	0.600 -	0.600
Mn	n	17		7		1	
	Mean±Sd	47.724 ±	90.917	42.791 ±	49.987	7.414 ±	0.000
	Range	3.811 -	341.458	6.696 -	142.870	7.414 -	7.414
Ni	n	1		0		0	
	Mean±Sd	6.150 ±	0.000				
	Range	6.150 -	6.150				
Zn	n	15		7		1	
	Mean±Sd	176.065 ±	176.061	245.096 ±	139.750	242.586 ±	0.000
	Range	54.019 -	776.068	107.873 -	509.799	242.586 -	242.586
DWF	n	17		7		1	
	Mean±Sd	0.287 ±	0.057	0.281 ±	0.040	0.228 ±	0.000
	Range	0.220 -	0.409	0.235 -	0.340	0.228 -	0.228

Appendix C3: The number, mean, standard deviation and range of the metal loads detected per tissue for each species sampled.

		O.mossambicus													
		Liver		Gills		Eggs		Fat		Flesh		Testes		Gut	
Al	n	26		13		1		0		1		0		0	
	Mean±Sd	133.443 ±	253.454	174.459 ±	169.145	55.725 ±	0.000			44.000 ±	0.000				
	Range	24.964 -	1330.000	35.829 -	638.797	55.725 -	55.725			44.000 -	44.000				
As	n	7		2		1		0		0		0		0	
	Mean±Sd	3.063 ±	2.152	1.804 ±	2.128	6.489 ±	0.000								
	Range	0.364 -	5.770	0.300 -	3.309	6.489 -	6.489								
Cd	n	54		13		4		2		4		2		1	
	Mean±Sd	0.874 ±	0.863	0.382 ±	0.335	0.343 ±	0.562	0.028 ±	0.018	0.204 ±	0.166	0.070 ±	0.078	4.500 ±	0.000
	Range	0.040 -	4.690	0.050 -	1.066	0.015 -	1.183	0.015 -	0.040	0.015 -	0.387	0.015 -	0.125	4.500 -	4.500
Cr	n	41		6		3		2		4		2		1	
	Mean±Sd	2.862 ±	3.334	1.081 ±	0.639	2.466 ±	3.405	0.710 ±	0.693	1.034 ±	0.960	1.919 ±	1.116	70.370 ±	0.000
	Range	0.279 -	13.600	0.500 -	1.762	0.190 -	6.380	0.220 -	1.200	0.180 -	2.280	1.130 -	2.708	70.370 -	70.370
Co	n	6		4		1		0		1		1		0	
	Mean±Sd	6.628 ±	4.456	1.251 ±	0.611	0.320 ±	0.000			0.320 ±	0.000	0.320 ±	0.000		
	Range	0.320 -	12.400	0.786 -	2.142	0.320 -	0.320			0.320 -	0.320	0.320 -	0.320		
Cu	n	55		17		4		2		4		2		1	
	Mean±Sd	671.586 ±	1226.757	12.459 ±	14.118	6.285 ±	2.355	0.540 ±	0.368	2.952 ±	1.980	9.607 ±	5.337	30.300 ±	0.000
	Range	3.934 -	6802.100	2.732 -	54.346	4.924 -	9.800	0.280 -	0.800	1.260 -	5.805	5.833 -	13.380	30.300 -	30.300
Fe	n	45		10		3		2		4		2		1	
	Mean±Sd	1505.478 ±	3452.111	391.818 ±	246.928	58.300 ±	14.534	29.600 ±	25.456	64.541 ±	65.803	202.575 ±	65.513	10.780 ±	0.000
	Range	0.480 -	21600.000	104.666 -	808.981	45.700 -	74.200	11.600 -	47.600	17.810 -	161.765	156.250 -	248.900	10.780 -	10.780
Mg	n	4		0		1		0		0		0		0	
	Mean±Sd	5.955 ±	2.639			0.650 ±	0.000								
	Range	3.200 -	8.520			0.650 -	0.650								
Pb	n	19		11		2		0		1		1		0	
	Mean±Sd	3.934 ±	13.872	1.415 ±	2.274	0.510 ±	0.156			0.620 ±	0.000	0.620 ±	0.000		
	Range	0.400 -	61.070	0.400 -	8.030	0.400 -	0.620			0.620 -	0.620	0.620 -	0.620		
Mn	n	53		17		3		2		4		2		1	
	Mean±Sd	14.412 ±	20.833	50.864 ±	38.508	8.515 ±	8.440	1.025 ±	0.247	2.216 ±	0.938	7.167 ±	7.189	680.180 ±	0.000
	Range	1.399 -	143.320	17.859 -	135.517	3.160 -	18.244	0.850 -	1.200	0.880 -	3.040	2.083 -	12.250	680.180 -	680.180
Ni	n	29		0		3		2		3		2		1	
	Mean±Sd	2.770 ±	2.229			1.431 ±	1.500	0.705 ±	0.134	0.945 ±	0.275	2.560 ±	1.853	41.670 ±	0.000
	Range	0.500 -	9.500			0.473 -	3.160	0.610 -	0.800	0.630 -	1.140	1.250 -	3.870	41.670 -	41.670
Zn	n	57		17		4		2		4		2		1	
	Mean±Sd	89.075 ±	63.373	103.334 ±	98.634	116.442 ±	20.025	2.555 ±	0.785	21.336 ±	10.285	88.741 ±	15.131	117.060 ±	0.000
	Range	35.130 -	406.010	41.520 -	451.005	94.886 -	143.000	2.000 -	3.110	6.579 -	30.180	78.042 -	99.440	117.060 -	117.060
Hg	n	5		2		1		0		0		0		0	
	Mean±Sd	0.057 ±	0.039	0.005 ±	0.003	0.007 ±	0.000								
	Range	0.020 -	0.110	0.003 -	0.007	0.007 -	0.007								
DWF	n	55		17		2		1		2		0		1	
	Mean±Sd	0.314 ±	0.073	0.314 ±	0.062	0.389 ±	0.109	0.815 ±	0.000	0.563 ±	0.542			0.180 ±	0.000
	Range	0.183 -	0.610	0.190 -	0.438	0.312 -	0.466	0.815 -	0.815	0.180 -	0.946			0.180 -	0.180

Appendix C3 : cont.

		C. carpio		*M.salmoides*		*M.dolomieu*	
		Liver	Gills	Liver	Gills	Liver	Gills
Al	n	7	3	1	1	1	1
	Mean±Sd	125.165 ± 234.922	67.438 ± 41.253	24.086 ± 0.000	154.374 ± 0.000	12.214 ± 0.000	12.208 ± 0.000
	Range	16.384 - 655.556	21.439 - 101.156	24.086 - 24.086	154.374 - 154.374	12.214 - 12.214	12.208 - 12.208
As	n	3	1	0	0	0	0
	Mean±Sd	2.205 ± 0.810	0.963 ± 0.000				
	Range	1.695 - 3.139	0.963 - 0.963				
Cd	n	7	3	1	1	1	1
	Mean±Sd	0.868 ± 0.838	0.815 ± 0.546	0.500 ± 0.000	0.500 ± 0.000	0.229 ± 0.000	0.500 ± 0.000
	Range	0.297 - 2.711	0.500 - 1.445	0.500 - 0.500	0.500 - 0.500	0.229 - 0.229	0.500 - 0.500
Cu	n	7	3	1	1	1	1
	Mean±Sd	125.581 ± 82.813	6.019 ± 2.388	14.784 ± 0.000	2.569 ± 0.000	3.130 ± 0.000	6.077 ± 0.000
	Range	51.297 - 297.210	3.907 - 8.610	14.784 - 14.784	2.569 - 2.569	3.130 - 3.130	6.077 - 6.077
Pb	n	7	3	1	1	1	1
	Mean±Sd	0.514 ± 0.107	0.533 ± 0.115	0.600 ± 0.000	0.600 ± 0.000	0.600 ± 0.000	0.600 ± 0.000
	Range	0.400 - 0.600	0.400 - 0.600	0.600 - 0.600	0.600 - 0.600	0.600 - 0.600	0.600 - 0.600
Mn	n	7	3	1	1	1	1
	Mean±Sd	11.999 ± 11.736	134.804 ± 39.004	9.676 ± 0.000	13.810 ± 0.000	7.366 ± 0.000	4.034 ± 0.000
	Range	3.079 - 34.861	90.051 - 161.561	9.676 - 9.676	13.810 - 13.810	7.366 - 7.366	4.034 - 4.034
Zn	n	7	3	1	1	1	1
	Mean±Sd	220.259 ± 78.284	382.151 ± 17.025	115.864 ± 0.000	56.129 ± 0.000	96.336 ± 0.000	49.230 ± 0.000
	Range	142.649 - 381.805	369.894 - 401.591	115.864 - 115.864	56.129 - 56.129	96.336 - 96.336	49.230 - 49.230
Hg	n	3	1	0	0	0	0
	Mean±Sd	0.090 ± 0.050	0.054 ± 0.000				
	Range	0.032 - 0.120	0.054 - 0.054				
DWF	n	7	3	1	1	1	1
	Mean±Sd	0.328 ± 0.075	0.235 ± 0.009	0.271 ± 0.000	0.358 ± 0.000	0.264 ± 0.000	0.378 ± 0.000
	Range	0.248 - 0.433	0.227 - 0.245	0.271 - 0.271	0.358 - 0.358	0.264 - 0.264	0.378 - 0.378

Appendix C3: cont.

		C.gariepinus											
		Liver		Gills		Eggs		Fat		Flesh		Testes	
Al	n	33		12		2		1		0		3	
	Mean±Sd	115.008 ±	173.058	290.063 ±	190.824	86.214 ±	65.356	30.000 ±	0.000			442.107 ±	563.903
	Range	7.785 -	797.000	104.730 -	683.750	40.000 -	132.428	30.000 -	30.000			10.000 -	1080.000
As	n	3		3		0		0		0		0	
	Mean±Sd	2.000 ±	0.000	2.000 ±	0.000								
	Range	2.000 -	2.000	2.000 -	2.000								
Cd	n	72		8		4		7		16		6	
	Mean±Sd	0.749 ±	0.704	0.751 ±	0.955	0.226 ±	0.423	0.159 ±	0.270	0.110 ±	0.071	0.330 ±	0.380
	Range	0.015 -	3.530	0.100 -	2.481	0.015 -	0.860	0.015 -	0.760	0.015 -	0.200	0.015 -	1.020
Cr	n	79		11		5		7		16		7	
	Mean±Sd	2.923 ±	3.471	2.813 ±	1.152	1.023 ±	0.567	3.528 ±	3.770	1.253 ±	0.618	2.170 ±	1.745
	Range	0.377 -	13.900	0.959 -	5.000	0.180 -	1.650	0.202 -	8.800	0.040 -	2.232	0.300 -	5.480
Co	n	22		7		2		3		6		3	
	Mean±Sd	7.616 ±	14.619	2.756 ±	3.341	4.646 ±	2.128	0.777 ±	0.791	0.320 ±	0.000	3.873 ±	1.032
	Range	0.100 -	49.540	0.100 -	6.890	3.141 -	6.150	0.320 -	1.690	0.320 -	0.320	3.019 -	5.020
Cu	n	85		18		4		6		16		5	
	Mean±Sd	62.769 ±	40.626	6.771 ±	3.019	5.991 ±	1.468	0.683 ±	0.362	2.067 ±	1.169	5.545 ±	0.695
	Range	8.796 -	197.600	3.979 -	16.192	4.075 -	7.310	0.300 -	1.317	1.130 -	5.346	4.860 -	6.540
Fe	n	91		19		9		7		16		7	
	Mean±Sd	2455.589 ±	4786.537	424.876 ±	436.769	313.960 ±	221.916	30.396 ±	40.905	70.253 ±	40.168	271.356 ±	294.971
	Range	1.000 -	37900.000	134.380 -	1806.452	156.530 -	872.581	0.050 -	115.770	16.380 -	134.960	82.890 -	917.780
Mg	n	1		0		0		0		0		0	
	Mean±Sd	6.960 ±	0.000										
	Range	6.960 -	6.960										
Pb	n	24		8		1		2		6		1	
	Mean±Sd	0.888 ±	1.075	3.160 ±	7.663	0.600 ±	0.000	0.620 ±	0.000	0.620 ±	0.000	15.425 ±	0.000
	Range	0.377 -	4.830	0.360 -	22.123	0.600 -	0.600	0.620 -	0.620	0.620 -	0.620	15.425 -	15.425
Mn	n	90		19		5		6		16		7	
	Mean±Sd	6.480 ±	3.888	45.218 ±	31.305	6.615 ±	4.839	1.040 ±	0.864	2.888 ±	2.547	28.139 ±	21.221
	Range	0.055 -	21.190	14.881 -	150.960	0.042 -	11.430	0.060 -	2.200	0.330 -	10.417	11.070 -	73.113
Ni	n	52		3		3		6		16		4	
	Mean±Sd	1.718 ±	2.323	0.565 ±	0.112	0.850 ±	0.271	2.267 ±	2.406	0.814 ±	0.398	1.773 ±	0.496
	Range	0.030 -	11.650	0.436 -	0.639	0.540 -	1.040	0.340 -	5.600	0.270 -	1.490	1.150 -	2.360
Zn	n	90		19		9		7		16		7	
	Mean±Sd	137.370 ±	75.888	156.451 ±	98.424	133.880 ±	56.289	3.502 ±	2.596	22.833 ±	12.505	121.974 ±	83.140
	Range	25.413 -	381.720	60.786 -	428.274	68.150 -	241.936	1.000 -	8.820	12.780 -	61.823	51.080 -	250.670
Hg	n	0		0		0		0		0		0	
	Mean±Sd												
	Range												
DWF	n	81		19		6		5		5		4	
	Mean±Sd	0.257 ±	0.054	0.310 ±	0.086	0.319 ±	0.086	0.939 ±	0.029	0.202 ±	0.023	0.202 ±	0.049
	Range	0.178 -	0.590	0.145 -	0.444	0.165 -	0.420	0.895 -	0.971	0.180 -	0.240	0.132 -	0.248

Appendix C3: cont.

		B. marequensis											
		Liver		Gills		Eggs		Fat		Flesh		Testes	
Al	n	9		2		0		0		0		0	
	Mean±Sd	73.018 ±	54.095	310.326 ±	185.723								
	Range	5.000 -	166.865	179.000 -	441.652								
As	n	2		1		0		0		0		0	
	Mean±Sd	2.270 ±	0.382	2.000 ±	0.000								
	Range	2.000 -	2.540	2.000 -	2.000								
Cd	n	27		2		5		4		10		3	
	Mean±Sd	0.719 ±	0.999	0.759 ±	0.932	0.037 ±	0.049	0.043 ±	0.055	0.126 ±	0.103	0.095 ±	0.095
	Range	0.015 -	4.540	0.100 -	1.418	0.015 -	0.125	0.015 -	0.125	0.015 -	0.290	0.015 -	0.200
Cr	n	23		1		5		4		10		3	
	Mean±Sd	3.329 ±	3.543	1.890 ±	0.000	0.762 ±	0.793	2.211 ±	2.468	1.131 ±	0.928	8.420 ±	6.481
	Range	0.025 -	13.700	1.890 -	1.890	0.025 -	1.997	0.270 -	5.600	0.140 -	3.380	1.360 -	14.100
Co	n	2		0		1		1		1		0	
	Mean±Sd	1.259 ±	1.327			0.320 ±	0.000	0.320 ±	0.000	0.320 ±	0.000		
	Range	0.320 -	2.197			0.320 -	0.320	0.320 -	0.320	0.320 -	0.320		
Cu	n	25		3		6		4		10		3	
	Mean±Sd	68.853 ±	116.047	4.546 ±	1.863	4.685 ±	2.144	0.856 ±	0.532	1.663 ±	0.449	7.353 ±	7.066
	Range	8.352 -	408.350	3.003 -	6.616	2.490 -	8.320	0.400 -	1.485	0.585 -	2.190	2.160 -	15.400
Fe	n	31		4		7		4		10		4	
	Mean±Sd	483.214 ±	483.459	632.080 ±	336.853	111.160 ±	70.351	131.145 ±	114.767	36.592 ±	20.537	379.030 ±	650.736
	Range	0.130 -	2299.400	325.075 -	1056.284	45.900 -	235.020	0.050 -	275.000	13.300 -	70.450	44.600 -	1355.000
Mg	n	1		0		0		0		0		1	
	Mean±Sd	4.470 ±	0.000									1.070 ±	0.000
	Range	4.470 -	4.470									1.070 -	1.070
Pb	n	3		0		1		1		1		0	
	Mean±Sd	1.855 ±	2.097			0.620 ±	0.000	0.620 ±	0.000	0.620 ±	0.000		
	Range	0.620 -	4.276			0.620 -	0.620	0.620 -	0.620	0.620 -	0.620		
Mn	n	30		4		6		4		10		2	
	Mean±Sd	10.223 ±	8.299	25.613 ±	6.937	4.619 ±	3.542	4.658 ±	2.953	3.208 ±	4.952	13.980 ±	17.847
	Range	3.898 -	40.800	15.596 -	30.700	1.590 -	10.753	2.000 -	7.760	0.418 -	17.150	1.360 -	26.600
Ni	n	21		1		5		4		10		3	
	Mean±Sd	1.982 ±	1.569	1.418 ±	0.000	1.156 ±	0.340	2.461 ±	1.734	0.656 ±	0.398	4.600 ±	3.201
	Range	0.360 -	6.600	1.418 -	1.418	0.830 -	1.690	1.230 -	5.000	0.190 -	1.320	1.260 -	7.640
Zn	n	30		4		7		4		10		4	
	Mean±Sd	90.807 ±	37.987	67.665 ±	14.263	176.187 ±	111.140	4.814 ±	2.470	15.145 ±	5.025	80.300 ±	28.993
	Range	26.460 -	233.135	57.656 -	88.779	65.920 -	409.247	2.480 -	7.290	4.495 -	24.520	49.700 -	105.900
DWF	n	26		4		2		1		5		3	
	Mean±Sd	0.265 ±	0.048	0.266 ±	0.025	0.318 ±	0.116	0.992 ±	0.000	0.210 ±	0.012	0.248 ±	0.029
	Range	0.206 -	0.426	0.238 -	0.298	0.236 -	0.400	0.992 -	0.992	0.200 -	0.230	0.215 -	0.270

Appendix C3: cont.

		S. intermedius				*L. molybdinus*					
		Liver		Flesh		Liver		Eggs		Flesh	
Al	n	5		0		0		0		0	
	Mean±Sd	48.161 ±	45.502								
	Range	9.804 -	115.000								
As	n	0		0		1		0		0	
	Mean±Sd					3.090 ±	0.000				
	Range					3.090 -	3.090				
Cd	n	11		1		9		3		6	
	Mean±Sd	0.733 ±	0.537	0.125 ±	0.000	1.186 ±	1.010	0.017 ±	0.003	0.062 ±	0.073
	Range	0.125 -	1.918	0.125 -	0.125	0.125 -	2.787	0.015 -	0.020	0.015 -	0.180
Cr	n	8		1		9		3		6	
	Mean±Sd	2.549 ±	2.171	2.291 ±	0.000	3.671 ±	4.443	0.463 ±	0.286	1.016 ±	0.834
	Range	0.481 -	6.400	2.291 -	2.291	0.600 -	14.800	0.260 -	0.790	0.270 -	2.593
Co	n	1		1		1		0		1	
	Mean±Sd	0.320 ±	0.000	0.320 ±	0.000	0.320 ±	0.000			0.320 ±	0.000
	Range	0.320 -	0.320	0.320 -	0.320	0.320 -	0.320			0.320 -	0.320
Cu	n	8		1		9		3		6	
	Mean±Sd	50.519 ±	19.237	3.109 ±	0.000	521.597 ±	610.632	8.190 ±	1.864	2.369 ±	0.679
	Range	19.800 -	79.300	3.109 -	3.109	70.980 -	2064.122	6.700 -	10.280	1.400 -	3.210
Fe	n	11		1		9		4		6	
	Mean±Sd	1140.542 ±	598.044	109.620 ±	0.000	258.461 ±	239.382	254.303 ±	128.073	62.213 ±	37.996
	Range	555.000 -	2175.000	109.620 -	109.620	0.210 -	738.200	79.210 -	380.700	21.950 -	122.800
Mg	n	2		0		0		0		0	
	Mean±Sd	2.375 ±	0.021								
	Range	2.360 -	2.390								
Pb	n	1		1		1		0		1	
	Mean±Sd	0.620 ±	0.000	0.620 ±	0.000	0.620 ±	0.000			0.620 ±	0.000
	Range	0.620 -	0.620	0.620 -	0.620	0.620 -	0.620			0.620 -	0.620
Mn	n	9		1		9		3		6	
	Mean±Sd	6.630 ±	2.472	8.181 ±	0.000	21.523 ±	12.785	3.070 ±	2.174	4.241 ±	1.879
	Range	3.700 -	12.431	8.181 -	8.181	5.100 -	41.020	1.310 -	5.500	2.060 -	6.483
Ni	n	6		1		9		3		6	
	Mean±Sd	0.941 ±	0.593	1.309 ±	0.000	1.906 ±	2.164	1.030 ±	0.202	0.991 ±	0.303
	Range	0.400 -	2.010	1.309 -	1.309	0.090 -	7.400	0.800 -	1.180	0.490 -	1.390
Zn	n	9		1		9		4		6	
	Mean±Sd	129.104 ±	40.624	39.709 ±	0.000	102.089 ±	58.077	165.608 ±	67.844	21.714 ±	6.049
	Range	80.500 -	219.300	39.709 -	39.709	49.060 -	201.840	67.210 -	212.800	12.680 -	28.330
DWF	n	10		0		5		1		1	
	Mean±Sd	0.231 ±	0.023			0.277 ±	0.044	0.390 ±	0.000	0.230 ±	0.000
	Range	0.186 -	0.274			0.228 -	0.342	0.390 -	0.390	0.230 -	0.230

Appendix C3: cont.

		T. rendalli											
		Liver		Gills		Eggs		Fat		Flesh		Testes	
Al	n	2		1		0		0		0		0	
	Mean±Sd	36.500 ±	9.192	89.000 ±	0.000								
	Range	30.000 -	43.000	89.000 -	89.000								
As	n	2		1		0		0		0		0	
	Mean±Sd	2.000 ±	0.000	2.000 ±	0.000								
	Range	2.000 -	2.000	2.000 -	2.000								
Cd	n	11		1		1		1		4		1	
	Mean±Sd	0.755 ±	0.721	1.627 ±	0.000	0.015 ±	0.000	0.015 ±	0.000	0.073 ±	0.067	0.015 ±	0.000
	Range	0.015 -	2.010	1.627 -	1.627	0.015 -	0.015	0.015 -	0.015	0.015 -	0.140	0.015 -	0.015
Cr	n	11		1		1		1		4		1	
	Mean±Sd	3.357 ±	3.180	1.085 ±	0.000	0.120 ±	0.000	0.300 ±	0.000	0.728 ±	0.543	0.380 ±	0.000
	Range	0.440 -	8.300	1.085 -	1.085	0.120 -	0.120	0.300 -	0.300	0.280 -	1.410	0.380 -	0.380
Cu	n	11		1		1		1		4		1	
	Mean±Sd	192.484 ±	228.038	4.881 ±	0.000	3.010 ±	0.000	0.310 ±	0.000	1.243 ±	0.227	8.210 ±	0.000
	Range	21.500 -	644.350	4.881 -	4.881	3.010 -	3.010	0.310 -	0.310	1.080 -	1.570	8.210 -	8.210
Fe	n	11		1		2		1		4		1	
	Mean±Sd	272.999 ±	260.209	174.078 ±	0.000	69.850 ±	12.657	30.600 ±	0.000	13.368 ±	4.358	133.400 ±	0.000
	Range	0.160 -	750.000	174.078 -	174.078	60.900 -	78.800	30.600 -	30.600	9.490 -	18.200	133.400 -	133.400
Mn	n	11		1		1		1		4		1	
	Mean±Sd	14.140 ±	13.278	55.315 ±	0.000	2.720 ±	0.000	1.720 ±	0.000	0.865 ±	0.237	20.380 ±	0.000
	Range	2.250 -	47.810	55.315 -	55.315	2.720 -	2.720	1.720 -	1.720	0.610 -	1.130	20.380 -	20.380
Ni	n	11		1		1		1		4		1	
	Mean±Sd	2.410 ±	1.740	27.657 ±	0.000	0.670 ±	0.000	0.660 ±	0.000	0.555 ±	0.320	2.390 ±	0.000
	Range	0.320 -	5.700	27.657 -	27.657	0.670 -	0.670	0.660 -	0.660	0.250 -	0.870	2.390 -	2.390
Zn	n	11		1		2		1		4		1	
	Mean±Sd	107.914 ±	51.188	473.970 ±	0.000	96.135 ±	18.519	5.870 ±	0.000	16.285 ±	3.091	96.960 ±	0.000
	Range	46.570 -	201.939	473.970 -	473.970	83.040 -	109.230	5.870 -	5.870	12.010 -	19.100	96.960 -	96.960
DWF	n	9		1		1		0		2		0	
	Mean±Sd	0.266 ±	0.066	0.260 ±	0.000	0.420 ±	0.000			0.245 ±	0.007		
	Range	0.170 -	0.416	0.260 -	0.260	0.420 -	0.420			0.240 -	0.250		

Appendix C3: cont.

		H.vittatus						*L.congoro*					
		Liver		Gills		Flesh		Liver		Gills		Flesh	
Al	n	2		0		0		12		5		0	
	Mean±Sd	22.988 ±	21.435					164.242 ±	157.143	259.044 ±	173.496		
	Range	7.831 -	38.144					9.000 -	496.000	90.756 -	503.000		
As	n	0		0		0		1		0		0	
	Mean±Sd							2.490 ±	0.000				
	Range							2.490 -	2.490				
Cd	n	3		0		2		19		4		2	
	Mean±Sd	0.108 ±	0.014			0.403 ±	0.392	2.752 ±	2.998	0.316 ±	0.250	0.225 ±	0.035
	Range	0.100 -	0.125			0.125 -	0.680	0.472 -	10.867	0.100 -	0.560	0.200 -	0.250
Cr	n	1		0		2		14		3		2	
	Mean±Sd	4.886 ±	0.000			2.012 ±	0.450	3.737 ±	2.777	1.664 ±	2.016	1.085 ±	0.021
	Range	4.886 -	4.886			1.693 -	2.330	0.500 -	9.320	0.500 -	3.992	1.070 -	1.100
Co	n	1		0		1		5		2		0	
	Mean±Sd	0.320 ±	0.000			0.320 ±	0.000	1.383 ±	0.581	1.406 ±	0.369		
	Range	0.320 -	0.320			0.320 -	0.320	0.534 -	1.931	1.145 -	1.667		
Cu	n	2		1		2		17		5		2	
	Mean±Sd	67.731 ±	5.038	2.503 ±	0.000	2.528 ±	1.029	692.676 ±	754.583	10.348 ±	4.829	1.490 ±	0.127
	Range	64.169 -	71.293	2.503 -	2.503	1.800 -	3.255	37.500 -	2881.016	4.518 -	15.278	1.400 -	1.580
Fe	n	4		1		2		23		7		2	
	Mean±Sd	3059.750 ±	1485.488	87.315 ±	0.000	40.380 ±	57.064	375.532 ±	318.495	349.892 ±	135.471	25.460 ±	4.045
	Range	1506.392 -	5029.320	87.315 -	87.315	0.030 -	80.730	0.170 -	1193.423	185.294 -	526.447	22.600 -	28.320
Pb	n	1		0		1		6		3		0	
	Mean±Sd	0.620 ±	0.000			0.620 ±	0.000	2.278 ±	4.600	0.433 ±	0.057		
	Range	0.620 -	0.620			0.620 -	0.620	0.400 -	11.667	0.400 -	0.499		
Mn	n	4		1		2		23		7		2	
	Mean±Sd	8.241 ±	5.393	17.548 ±	0.000	6.308 ±	3.970	11.162 ±	12.584	49.490 ±	12.218	2.700 ±	0.255
	Range	4.828 -	16.287	17.548 -	17.548	3.500 -	9.115	2.095 -	56.677	29.081 -	66.423	2.520 -	2.880
Ni	n	1		0		2		8		0		2	
	Mean±Sd	1.629 ±	0.000			0.896 ±	0.390	2.085 ±	1.978			0.410 ±	0.297
	Range	1.629 -	1.629			0.620 -	1.172	0.280 -	5.600			0.200 -	0.620
Zn	n	4		1		2		21		7		2	
	Mean±Sd	199.244 ±	120.840	99.261 ±	0.000	21.480 ±	5.389	111.700 ±	92.157	313.544 ±	143.075	19.440 ±	0.212
	Range	118.711 -	379.095	99.261 -	99.261	17.669 -	25.290	37.380 -	349.866	110.524 -	510.602	19.290 -	19.590
DWF	n	3		1		1		23		7		2	
	Mean±Sd	0.262 ±	0.007	0.348 ±	0.000	0.230 ±	0.000	0.325 ±	0.075	0.266 ±	0.025	0.190 ±	0.000
	Range	0.255 -	0.269	0.348 -	0.348	0.230 -	0.230	0.210 -	0.530	0.237 -	0.303	0.190 -	0.190

Appendix C3: cont.

		L.rosae						*L.ruddi*				*H.molitrix*	
		Liver		Gills		Gut		Liver		Gills		Liver	
Al	n	13		0		1		4		3		1	
	Mean±Sd	237.829 ±	295.730			9782.016 ±	0.000	41.845 ±	52.892	155.338 ±	139.235	40.984 ±	0.000
	Range	12.000 -	1056.641			9782.016 -	9782.016	7.711 -	120.690	42.474 -	310.930	40.984 -	40.984
Cd	n	14		0		1		4		3		1	
	Mean±Sd	2.192 ±	1.942			0.490 ±	0.000	0.344 ±	0.293	0.238 ±	0.239	0.373 ±	0.000
	Range	0.342 -	7.660			0.490 -	0.490	0.100 -	0.687	0.100 -	0.513	0.373 -	0.373
Cr	n	7		0		1		4		3		1	
	Mean±Sd	4.734 ±	5.666			67.711 ±	0.000	1.595 ±	2.189	3.647 ±	2.733	1.751 ±	0.000
	Range	0.427 -	16.830			67.711 -	67.711	0.500 -	4.878	0.500 -	5.416	1.751 -	1.751
Co	n	2		0		1		3		3		1	
	Mean±Sd	3.031 ±	0.488			9.591 ±	0.000	0.296 ±	0.339	0.545 ±	0.771	2.049 ±	0.000
	Range	2.686 -	3.376			9.591 -	9.591	0.100 -	0.687	0.100 -	1.435	2.049 -	2.049
Cu	n	8		1		1		4		3		1	
	Mean±Sd	856.033 ±	744.698	8.993 ±	0.000	30.109 ±	0.000	1872.702 ±	1408.534	18.326 ±	13.554	222.355 ±	0.000
	Range	26.172 -	2195.060	8.993 -	8.993	30.109 -	30.109	224.138 -	3662.541	4.989 -	32.087	222.355 -	222.355
Fe	n	15		1		1		4		3		1	
	Mean±Sd	1020.784 ±	1492.493	440.647 ±	0.000	2128.978 ±	0.000	1512.808 ±	2689.082	268.110 ±	144.878	1719.449 ±	0.000
	Range	1.950 -	4765.625	440.647 -	440.647	2128.978 -	2128.978	111.932 -	5545.959	126.824 -	416.332	1719.449 -	1719.449
Pb	n	2		0		1		3		3		1	
	Mean±Sd	454.712 ±	600.178			3.406 ±	0.000	0.400 ±	0.000	0.400 ±	0.000	0.600 ±	0.000
	Range	30.322 -	879.103			3.406 -	3.406	0.400 -	0.400	0.400 -	0.400	0.600 -	0.600
Mn	n	15		1		1		4		3		1	
	Mean±Sd	27.007 ±	52.947	64.748 ±	0.000	341.458 ±	0.000	10.318 ±	5.858	86.090 ±	50.233	7.414 ±	0.000
	Range	3.811 -	208.670	64.748 -	64.748	341.458 -	341.458	6.696 -	19.073	47.434 -	142.870	7.414 -	7.414
Ni	n	1		0		0		0		0		0	
	Mean±Sd	6.150 ±	0.000										
	Range	6.150 -	6.150										
Zn	n	13		1		1		4		3		1	
	Mean±Sd	180.624 ±	185.934	238.849 ±	0.000	54.019 ±	0.000	153.225 ±	39.799	367.592 ±	129.716	242.586 ±	0.000
	Range	79.650 -	776.068	238.849 -	238.849	54.019 -	54.019	107.873 -	200.976	255.758 -	509.799	242.586 -	242.586
DWF	n	15		1		1		4		3		1	
	Mean±Sd	0.278 ±	0.051	0.300 ±	0.000	0.409 ±	0.000	0.282 ±	0.036	0.279 ±	0.053	0.228 ±	0.000
	Range	0.220 -	0.388	0.300 -	0.300	0.409 -	0.409	0.235 -	0.319	0.244 -	0.340	0.228 -	0.228

Appendix C4: The number (N), mean, standard deviation and range of the metals (µg/g dry weight) body loads in all the rivers sampled.

		Berg		Crocodile		Letaba		Luvuvhu		Olifants		Sabie	
Al	n	34		11		22		0		68		33	
	Mean±Sd	88.323 ±	119.327	92.091 ±	91.068	611.892 ±	2067.664			213.790 ±	239.656	86.577 ±	93.537
	Range	12.208 -	655.556	8.000 -	308.000	19.108 -	9782.020			7.711 -	1080.000	5.000 -	441.652
As	n	13		15		0		0		0		0	
	Mean±Sd	2.711 ±	2.099	2.267 ±	0.547								
	Range	0.300 -	6.489	2.000 -	3.880								
Cd	n	34		178		70		0		45		33	
	Mean±Sd	0.692 ±	0.440	0.693 ±	1.107	0.693 ±	0.761			1.159 ±	2.224	0.866 ±	0.734
	Range	0.229 -	2.711	0.015 -	7.660	0.030 -	4.540			0.050 -	10.867	0.100 -	3.256
Cr	n	0		178		70		0		68		0	
	Mean±Sd			3.215 ±	6.111	3.642 ±	8.377			2.003 ±	1.550		
	Range			0.025 -	70.370	0.279 -	67.710			0.300 -	5.550		
Co	n	0		27		1		0		58		0	
	Mean±Sd			0.320 ±	0.000	9.591 ±	0.000			4.927 ±	9.411		
	Range			0.320 -	0.320	9.591 -	9.590			0.100 -	49.540		
Cu	n	34		178		70		37		61		0	
	Mean±Sd	61.598 ±	83.693	97.650 ±	274.994	300.898 ±	434.401	194.484 ±	524.796	519.688 ±	1277.985		
	Range	2.569 -	297.210	0.280 -	2195.060	0.300 -	2135.420	2.503 -	2881.016	3.979 -	6802.100		
Fe	n	0		186		70		37		68		33	
	Mean±Sd			653.373 ±	1948.157	2133.750 ±	5465.285	975.115 ±	994.590	941.297 ±	1017.749	922.715 ±	1034.747
	Range			0.030 -	17570.910	15.000 -	37900.000	24.793 -	3864.068	82.890 -	4765.625	171.491 -	4175.548
Mg	n	0		0		10		0		0		0	
	Mean±Sd					4.172 ±	2.788						
	Range					0.650 -	8.520						
Pb	n	34		27		1		0		61		0	
	Mean±Sd	0.524 ±	0.099	0.620 ±	0.000	3.406 ±	0.000			17.589 ±	112.519		
	Range	0.400 -	0.600	0.620 -	0.620	3.406 -	3.410			0.360 -	879.103		
Mn	n	34		178		59		37		68		33	
	Mean±Sd	23.132 ±	38.177	16.468 ±	55.470	17.726 ±	46.909	75.483 ±	296.115	20.652 ±	26.704	11.716 ±	13.283
	Range	2.513 -	161.561	0.289 -	680.180	1.200 -	341.460	3.317 -	1820.765	0.042 -	142.870	2.095 -	51.726
Ni	n	0		178		48		0		0		0	
	Mean±Sd			2.130 ±	4.027	1.731 ±	1.785						
	Range			0.030 -	41.670	0.050 -	7.640						
Zn	n	34		186		70		37		68		25	
	Mean±Sd	134.804 ±	104.284	84.124 ±	72.713	94.546 ±	46.373	199.969 ±	124.645	170.065 ±	130.384	114.190 ±	59.719
	Range	41.920 -	401.591	1.800 -	473.970	1.000 -	219.300	50.556 -	451.005	8.820 -	776.068	38.471 -	285.728
Hg	n	12		0		0		0		0		0	
	Mean±Sd	0.052 ±	0.045									±	
	Range	0.003 -	0.120									-	
DWF	n	34		106.000		70		37		68		30	
	Mean±Sd	0.336 ±	0.067	0.284	0.148	0.310 ±	0.151	0.296 ±	0.039	0.284 ±	0.095	0.291 ±	0.073
	Range	0.227 -	0.467	0.170	0.990	0.132 -	0.960	0.223 -	0.410	0.145 -	0.895	0.215 -	0.530

Appendix C5: The number, mean, range and standard deviation of the metals detected in the fish tissues analyzed per sampling site in each river sampled.

		Berg			
		Misverst		Voëlvlei	
Al	n	24		10	
	Mean±Sd	111.068 ±	135.299	33.733 ±	27.148
	Range	24.086 -	655.556	12.208 -	101.156
As	n	7		6	
	Mean±Sd	2.476 ±	2.302	2.984 ±	2.011
	Range	0.300 -	5.765	0.963 -	6.489
Cd	n	24		10	
	Mean±Sd	0.604 ±	0.188	0.901 ±	0.741
	Range	0.342 -	1.066	0.229 -	2.711
Cu	n	24		10	
	Mean±Sd	56.840 ±	83.828	73.018 ±	86.715
	Range	2.569 -	297.210	3.130 -	259.282
Pb	n	24		10	
	Mean±Sd	0.542 ±	0.093	0.480 ±	0.103
	Range	0.400 -	0.600	0.400 -	0.600
Mn	n	24		10	
	Mean±Sd	17.497 ±	19.753	36.655 ±	63.710
	Range	2.513 -	90.051	3.079 -	161.561
Zn	n	24		10	
	Mean±Sd	111.748 ±	90.888	190.138 ±	118.090
	Range	41.920 -	381.805	49.230 -	401.591
Hg	n	6		6	
	Mean±Sd	0.030 ±	0.028	0.074 ±	0.049
	Range	0.003 -	0.076	0.007 -	0.120
DWF	n	24		10	
	Mean±Sd	0.339 ±	0.067	0.327 ±	0.071
	Range	0.244 -	0.467	0.227 -	0.433

Appendix C5: cont.

		Crocodile							
		LionsClub		Mataffin		Riverside		Tenbosch	
Al	n	3		3		0		3	
	Mean±Sd	149.000 ±	142.454	63.000 ±	80.988			54.000 ±	31.000
	Range	33.000 -	308.000	8.000 -	156.000			30.000 -	89.000
As	n	4		3		2		4	
	Mean±Sd	2.135 ±	0.270	2.000 ±	0.000	2.790 ±	0.424	2.470 ±	0.940
	Range	2.000 -	2.540	2.000 -	2.000	2.490 -	3.090	2.000 -	3.880
Cd	n	33		14		34		49	
	Mean±Sd	0.635 ±	0.865	0.545 ±	0.420	0.743 ±	1.414	0.967 ±	1.411
	Range	0.015 -	3.530	0.040 -	1.279	0.015 -	7.660	0.015 -	5.810
Cr	n	33		14		34		49	
	Mean±Sd	4.070 ±	4.671	1.765 ±	1.284	3.144 ±	3.866	3.889 ±	10.148
	Range	0.202 -	14.800	0.428 -	4.830	0.300 -	16.830	0.120 -	70.370
Co	n	10		1		8		8	
	Mean±Sd	0.320 ±	0.000	0.320 ±	0.000	0.320 ±	0.000	0.320 ±	0.000
	Range	0.320 -	0.320	0.320 -	0.320	0.320 -	0.320	0.320 -	0.320
Cu	n	33		14		34		49	
	Mean±Sd	84.682 ±	254.846	50.614 ±	107.316	220.000 ±	507.671	108.165 ±	192.496
	Range	0.400 -	1466.610	1.350 -	408.350	0.585 -	2195.060	0.280 -	644.350
Fe	n	34		16		35		50	
	Mean±Sd	862.864 ±	2149.519	387.533 ±	593.965	940.397 ±	2970.281	508.640 ±	997.198
	Range	0.210 -	11153.400	21.590 -	1859.000	0.340 -	17570.910	0.030 -	5029.320
Pb	n	10		1		8		8	
	Mean±Sd	0.620 ±	0.000	0.620 ±	0.000	0.620 ±	0.000	0.620 ±	0.000
	Range	0.620 -	0.620	0.620 -	0.620	0.620 -	0.620	0.620 -	0.620
Mn	n	33		14		34		49	
	Mean±Sd	21.355 ±	36.815	8.474 ±	11.375	17.523 ±	35.865	25.775 ±	96.214
	Range	0.289 -	150.960	1.393 -	46.356	0.418 -	208.670	0.610 -	680.180
Ni	n	33		14		34		49	
	Mean±Sd	1.882 ±	2.647	1.484 ±	1.527	1.777 ±	1.685	3.209 ±	6.937
	Range	0.030 -	11.650	0.310 -	5.901	0.200 -	6.600	0.250 -	41.670
Zn	n	34		16		35		50	
	Mean±Sd	87.683 ±	72.222	79.391 ±	77.226	94.876 ±	85.296	84.664 ±	72.665
	Range	1.800 -	276.480	14.430 -	290.773	4.495 -	409.250	3.110 -	473.970
DWF	n	15		15		16		28	
	Mean±Sd	0.320 ±	0.183	0.268 ±	0.079	0.255 ±	0.060	0.247 ±	0.056
	Range	0.188 -	0.940	0.178 -	0.444	0.170 -	0.380	0.180 -	0.420

Appendix C5: cont.

		Crocodile					
		Croc.Hotel		HengelClub		Rivuletts	
Al	n	0		0		2	
	Mean±Sd					107.500 ±	101.116
	Range					36.000 -	179.000
As	n	0		0		2	
	Mean±Sd					2.000 ±	0.000
	Range					2.000 -	2.000
Cd	n	14		26		8	
	Mean±Sd	0.209 ±	0.269	0.466 ±	0.691	0.889 ±	1.027
	Range	0.015 -	0.710	0.015 -	2.790	0.015 -	3.010
Cr	n	14		26		8	
	Mean±Sd	2.131 ±	2.960	1.843 ±	1.868	4.765 ±	3.656
	Range	0.025 -	8.800	0.040 -	8.800	0.557 -	10.000
Cu	n	14		26		8	
	Mean±Sd	13.035 ±	15.554	26.760 ±	41.930	27.535 ±	27.006
	Range	0.430 -	49.140	1.110 -	197.600	0.400 -	63.750
Fe	n	15		28		8	
	Mean±Sd	130.302 ±	144.458	850.389 ±	2590.387	234.766 ±	389.631
	Range	0.050 -	464.200	1.070 -	13719.700	0.050 -	1104.000
Mn	n	14		26		8	
	Mean±Sd	4.467 ±	2.745	5.327 ±	4.193	6.013 ±	4.671
	Range	0.810 -	10.290	0.330 -	18.050	1.100 -	15.596
Ni	n	14		26		8	
	Mean±Sd	1.499 ±	1.744	1.223 ±	1.063	3.236 ±	2.334
	Range	0.190 -	5.600	0.060 -	4.800	0.090 -	6.900
Zn	n	15		28		8	
	Mean±Sd	47.991 ±	38.587	92.793 ±	73.071	65.456 ±	47.987
	Range	2.910 -	124.610	7.290 -	275.250	2.480 -	147.200
DWF	n	10		14		8	
	Mean±Sd	0.334 ±	0.234	0.250 ±	0.063	0.423 ±	0.334
	Range	0.200 -	0.971	0.180 -	0.420	0.208 -	0.992

Appendix C5: cont.

		Letaba									
		Hudson		Midlet		Junction		Slab		Prieska	
Al	n	5		5		2		3		4	
	Mean±Sd	2107.697 ±	4296.085	111.629 ±	60.994	190.000 ±	50.910	64.333 ±	25.541	364.500 ±	643.749
	Range	19.108 -	9782.016	20.795 -	179.276	154.000 -	226.000	44.000 -	93.000	31.000 -	1330.000
Cd	n	5		5		12		14		21	
	Mean±Sd	0.565 ±	0.592	0.310 ±	0.470	0.814 ±	0.510	0.587 ±	0.419	0.808 ±	1.114
	Range	0.100 -	1.546	0.100 -	1.151	0.040 -	1.710	0.040 -	1.770	0.030 -	4.540
Cr	n	5		5		12		14		21	
	Mean±Sd	15.192 ±	29.436	0.643 ±	0.319	3.486 ±	3.150	1.694 ±	1.966	2.998 ±	3.301
	Range	0.500 -	67.711	0.500 -	1.214	0.329 -	9.270	0.387 -	7.430	0.279 -	10.730
Co	n	1		0		0		0		0	
	Mean±Sd	9.591 ±	0.000								
	Range	9.591 -	9.591								
Cu	n	5		5		12		14		21	
	Mean±Sd	231.231 ±	426.158	491.264 ±	922.995	440.141 ±	454.790	369.115 ±	496.751	122.592 ±	175.193
	Range	3.941 -	990.722	15.597 -	2135.417	9.800 -	1405.980	0.800 -	1731.700	0.300 -	600.000
Fe	n	5		5		12		14		21	
	Mean±Sd	616.440 ±	862.102	2892.631 ±	2846.235	7227.655 ±	11750.340	818.807 ±	1783.563	1168.801 ±	1814.874
	Range	87.246 -	2128.978	252.763 -	6273.000	45.700 -	37900.000	47.600 -	6900.000	15.000 -	8670.000
Mg	n	0		0		3		1		2	
	Mean±Sd					3.603 ±	3.170	7.880 ±	0.000	3.290 ±	1.315
	Range					0.650 -	6.960	7.880 -	7.880	2.360 -	4.220
Pb	n	1		0		0		0		0	
	Mean±Sd	3.406 ±	0.000								
	Range	3.406 -	3.406								
Mn	n	5		5		9		13		18	
	Mean±Sd	74.894 ±	149.139	38.726 ±	54.979	12.797 ±	10.870	5.219 ±	2.999	9.952 ±	9.405
	Range	1.399 -	341.458	3.810 -	135.517	3.460 -	35.310	1.200 -	9.260	3.300 -	39.086
Ni	n	0		0		10		11		17	
	Mean±Sd					2.198 ±	1.600	1.419 ±	1.489	1.343 ±	1.701
	Range					0.050 -	4.480	0.160 -	4.590	0.090 -	6.270
Zn	n	5		5		12		14		21	
	Mean±Sd	97.632 ±	77.472	145.620 ±	15.460	97.298 ±	44.560	68.530 ±	41.661	88.831 ±	37.593
	Range	35.130 -	209.501	127.368 -	166.379	45.040 -	188.200	2.000 -	138.400	1.000 -	193.900
DWF	n	5		5		12		14		21	
	Mean±Sd	0.405 ±	0.135	0.261 ±	0.054	0.313 ±	0.070	0.384 ±	0.230	0.277 ±	0.163
	Range	0.277 -	0.605	0.190 -	0.335	0.217 -	0.470	0.213 -	0.946	0.132 -	0.958

Appendix C5: cont.

		Letaba							
		PumpStation		Engelhardt		EngelhardtDrift		Camp16	
Al	n	1		0		0		2	
	Mean±Sd	125.000 ±	0.000					104.500 ±	43.134
	Range	125.000 -	125.000					74.000 -	135.000
Cd	n	8		2		1		2	
	Mean±Sd	0.391 ±	0.310	0.700 ±	0.467	0.290 ±	0.000	2.173 ±	0.360
	Range	0.040 -	1.070	0.370 -	1.030	0.290 -	0.290	1.918 -	2.427
Cr	n	8		2		1		2	
	Mean±Sd	5.203 ±	4.947	1.615 ±	0.700	1.170 ±	0.000	0.623 ±	0.023
	Range	0.300 -	14.100	1.120 -	2.110	1.170 -	1.170	0.607 -	0.639
Cu	n	8		2		1		2	
	Mean±Sd	305.512 ±	352.963	170.300 ±	124.592	514.000 ±	0.000	563.967 ±	716.188
	Range	4.500 -	984.800	82.200 -	258.400	514.000 -	514.000	57.545 -	1070.388
Fe	n	8		2		1		2	
	Mean±Sd	688.947 ±	649.572	758.350 ±	145.452	246.200 ±	0.000	901.330 ±	135.923
	Range	47.700 -	2175.000	655.500 -	861.200	246.200 -	246.200	805.218 -	997.442
Mg	n	4		0		0		0	
	Mean±Sd	4.113 ±	3.255						
	Range	1.070 -	8.520						
Mn	n	4		2		1		2	
	Mean±Sd	8.616 ±	7.806	6.885 ±	5.494	8.700 ±	0.000	29.306 ±	31.498
	Range	3.300 -	20.200	3.000 -	10.770	8.700 -	8.700	7.033 -	51.578
Ni	n	7		2		1		0	
	Mean±Sd	2.806 ±	2.623	0.500 ±	0.184	2.040 ±	0.000		
	Range	0.410 -	7.640	0.370 -	0.630	2.040 -	2.040		
Zn	n	8		2		1		2	
	Mean±Sd	111.328 ±	52.348	97.850 ±	36.557	56.800 ±	0.000	133.202 ±	14.173
	Range	64.000 -	219.300	72.000 -	123.700	56.800 -	56.800	123.180 -	143.223
DWF	n	8		2		1		2	
	Mean±Sd	0.268 ±	0.056	0.234 ±	0.010	0.295 ±	0.000	0.248 ±	0.005
	Range	0.186 -	0.345	0.227 -	0.241	0.295 -	0.295	0.244 -	0.251

Appendix C5: cont.

		Luvhuvu							
		Farm		Mkuyadownstream		Mkuyaupstream		Settlement	
Cu	n	11		5		15		6	
	Mean±Sd	32.131 ±	44.596	64.087 ±	58.651	385.228 ±	792.665	123.933 ±	163.791
	Range	3.003 -	138.980	2.503 -	121.282	4.004 -	2881.016	5.027 -	348.264
Fe	n	11		5		15		6	
	Mean±Sd	490.766 ±	479.838	1514.107 ±	1328.155	1078.110 ±	1091.860	1156.438 ±	1017.190
	Range	24.793 -	1748.025	87.315 -	3018.196	145.277 -	3864.068	347.185 -	3046.181
Mn	n	11		5		15		6	
	Mean±Sd	191.552 ±	541.608	13.629 ±	12.274	27.374 ±	22.869	34.510 ±	25.278
	Range	3.317 -	1820.765	4.455 -	33.441	4.011 -	66.423	6.439 -	63.586
Zn	n	11		5		15		6	
	Mean±Sd	114.589 ±	79.910	276.699 ±	134.640	222.450 ±	110.161	236.351 ±	159.937
	Range	50.556 -	326.184	99.261 -	381.724	76.749 -	376.323	55.630 -	451.005
DWF	n	11		5		15		6	
	Mean±Sd	0.293 ±	0.044	0.299 ±	0.041	0.292 ±	0.044	0.304 ±	0.016
	Range	0.236 -	0.410	0.248 -	0.348	0.223 -	0.388	0.282 -	0.323

Appendix C5: cont.

		Olifants							
		Arabie		Baluli		MambaWeir		Selati	
Al	n	11		9		12		12	
	Mean±Sd	259.714 ±	328.445	262.094 ±	367.988	169.686 ±	136.701	72.543 ±	83.769
	Range	13.393 -	1056.641	10.000 -	1080.000	7.785 -	448.778	7.711 -	310.930
Cd	n	11		9		12		12	
	Mean±Sd	0.743 ±	1.370	0.562 ±	0.475	2.773 ±	3.710	0.398 ±	0.454
	Range	0.050 -	4.786	0.100 -	1.210	0.100 -	10.867	0.100 -	1.563
Cr	n	11		9		12		12	
	Mean±Sd	2.158 ±	0.986	2.231 ±	1.941	2.193 ±	1.866	1.673 ±	2.075
	Range	1.118 -	4.487	0.300 -	5.480	0.500 -	5.550	0.500 -	5.416
Co	n	11		9		12		12	
	Mean±Sd	3.057 ±	1.718	10.696 ±	18.573	1.293 ±	0.708	5.993 ±	12.484
	Range	0.937 -	6.776	0.100 -	49.540	0.100 -	2.166	0.100 -	43.210
Cu	n	11		5		11		11	
	Mean±Sd	330.298 ±	484.760	31.333 ±	35.766	280.693 ±	364.834	1834.016 ±	2523.828
	Range	16.411 -	1254.987	3.979 -	78.825	5.426 -	978.463	4.989 -	6802.100
Fe	n	11		9		12		12	
	Mean±Sd	2203.176 ±	1619.980	966.403 ±	1124.585	727.663 ±	718.102	560.216 ±	559.290
	Range	411.919 -	4765.625	82.890 -	3404.376	115.770 -	2154.190	111.932 -	1657.415
Pb	n	11		5		11		11	
	Mean±Sd	83.166 ±	264.133	0.400 ±	0.000	0.400 ±	0.000	1.693 ±	2.535
	Range	0.600 -	879.103	0.400 -	0.400	0.400 -	0.400	0.400 -	8.030
Mn	n	11		9		12		12	
	Mean±Sd	26.143 ±	32.801	17.409 ±	14.527	12.013 ±	16.426	29.459 ±	40.785
	Range	5.042 -	104.819	3.349 -	45.438	0.060 -	48.795	5.352 -	142.870
Zn	n	11		9		12		12	
	Mean±Sd	169.641 ±	215.149	142.325 ±	52.065	163.002 ±	155.039	176.548 ±	133.642
	Range	46.480 -	776.068	51.080 -	250.670	8.820 -	510.602	58.154 -	509.799
DWF	n	11		9		12		12	
	Mean±Sd	0.291 ±	0.057	0.284 ±	0.058	0.361 ±	0.174	0.288 ±	0.026
	Range	0.224 -	0.373	0.216 -	0.395	0.237 -	0.895	0.244 -	0.340

Appendix C5: cont.

		Olifants							
		Vyeboom		PreSelati		PostSelati		Klipspruit	
Al	n	1		1		9		13	
	Mean±Sd	40.000 ±	0.000	677.000 ±	0.000	316.111 ±	260.733	219.482 ±	133.262
	Range	40.000 -	40.000	677.000 -	677.000	45.000 -	797.000	36.376 -	561.680
Cd	n	1		0		0		0	
	Mean±Sd	0.860 ±	0.000						
	Range	0.860 -	0.860						
Cr	n	1		1		9		13	
	Mean±Sd	1.220 ±	0.000	1.623 ±	0.000	2.150 ±	1.695	1.830 ±	0.853
	Range	1.220 -	1.220	1.623 -	1.623	0.377 -	4.570	0.764 -	3.175
Co	n	1		0		0		13	
	Mean±Sd	6.150 ±	0.000					4.791 ±	1.514
	Range	6.150 -	6.150					2.197 -	6.913
Cu	n	0		1		9		13	
	Mean±Sd			103.896 ±	0.000	485.755 ±	857.094	13.347 ±	10.045
	Range			103.896 -	103.896	7.914 -	2051.527	4.075 -	28.741
Fe	n	1		1		9		13	
	Mean±Sd	195.380 ±	0.000	1049.784 ±	0.000	684.764 ±	196.439	631.774 ±	341.449
	Range	195.380 -	195.380	1049.784 -	1049.784	366.547 -	975.922	258.019 -	1275.055
Pb	n	0		1		9		13	
	Mean±Sd			0.541 ±	0.000	8.622 ±	20.006	4.227 ±	6.781
	Range			0.541 -	0.541	0.360 -	61.069	0.600 -	22.123
Mn	n	1		1		9		13	
	Mean±Sd	3.860 ±	0.000	11.364 ±	0.000	19.928 ±	23.770	20.604 ±	24.015
	Range	3.860 -	3.860	11.364 -	11.364	3.981 -	63.309	0.042 -	73.113
Zn	n	1		1		9		13	
	Mean±Sd	175.300 ±	0.000	127.165 ±	0.000	162.561 ±	109.271	198.255 ±	80.261
	Range	175.300 -	175.300	127.165 -	127.165	62.500 -	406.011	114.583 -	428.274
DWF	n	1		1		9		13	
	Mean±Sd	0.300 ±	0.000	0.297 ±	0.000	0.297 ±	0.018	0.190 ±	0.032
	Range	0.300 -	0.300	0.297 -	0.297	0.272 -	0.321	0.145 -	0.253

Appendix C5: cont.

		Sabie Weir	
Al	n	33	
	Mean±Sd	86.577 ±	93.537
	Range	5.000 -	441.652
Cd	n	33	
	Mean±Sd	0.866 ±	0.734
	Range	0.100 -	3.256
Fe	n	33	
	Mean±Sd	922.715 ±	1034.747
	Range	171.491 -	4175.548
Mn	n	33	
	Mean±Sd	11.716 ±	13.283
	Range	2.095 -	51.726
Zn	n	25	
	Mean±Sd	114.190 ±	59.719
	Range	38.471 -	285.728
DWF	n	33	
	Mean±Sd	0.291 ±	0.073
	Range	0.215 -	0.530

Appendix C6: The number, mean, standard deviation and range of the metal loads detected per species for each river sampled

		Berg							
		O.mossambicus		*C.carpio*		*M.salmoides*		*M.dolomieu*	
Al	n	20		10		2		2	
	Mean±Sd	86.081 ±	74.113	107.847 ±	194.803	89.230 ±	92.128	12.211 ±	0.004
	Range	29.144 -	266.351	16.384 -	655.556	24.086 -	154.374	12.208 -	12.214
As	n	9		4		0		0	
	Mean±Sd	3.073 ±	2.412	1.895 ±	0.907				
	Range	0.300 -	6.489	0.963 -	3.139				
Cd	n	20		10		2		2	
	Mean±Sd	0.663 ±	0.225	0.852 ±	0.731	0.500 ±	0.000	0.365 ±	0.192
	Range	0.500 -	1.183	0.297 -	2.711	0.500 -	0.500	0.229 -	0.500
Cu	n	20		10		2		2	
	Mean±Sd	58.532 ±	85.747	89.712 ±	88.931	8.676 ±	8.638	4.604 ±	2.084
	Range	2.732 -	259.282	3.907 -	297.210	2.569 -	14.784	3.130 -	6.077
Pb	n	20		10		2		2	
	Mean±Sd	0.510 ±	0.102	0.520 ±	0.103	0.600 ±	0.000	0.600 ±	0.000
	Range	0.400 -	0.600	0.400 -	0.600	0.600 -	0.600	0.600 -	0.600
Mn	n	20		10		2		2	
	Mean±Sd	13.159 ±	12.726	48.841 ±	62.840	11.743 ±	2.923	5.700 ±	2.356
	Range	2.513 -	43.824	3.079 -	161.561	9.676 -	13.810	4.034 -	7.366
Zn	n	20		10		2		2	
	Mean±Sd	78.875 ±	21.710	268.827 ±	101.318	85.996 ±	42.239	72.783 ±	33.309
	Range	41.920 -	114.668	142.649 -	401.591	56.129 -	115.864	49.230 -	96.336
Hg	n	8		4		0		0	
	Mean±Sd	0.038 ±	0.040	0.081 ±	0.044				
	Range	0.003 -	0.114	0.032 -	0.120				
DWF	n	20		10		2		2	
	Mean±Sd	0.357 ±	0.058	0.300 ±	0.076	0.315 ±	0.062	0.321 ±	0.081
	Range	0.259 -	0.467	0.227 -	0.433	0.271 -	0.358	0.264 -	0.378

Appendix C6: cont.

		Crocodile									
		O.mossambicus		*C.gariepinus*		*S.intermedius*		*B.marequensis*		*L.molybdinus*	
Al	n	0		6		0		2		0	
	Mean±Sd			106.000 ±	113.840			107.500 ±	101.116		
	Range			8.000 -	308.000			36.000 -	179.000		
As	n	1		6		0		3		1	
	Mean±Sd	3.880 ±	0.000	2.000 ±	0.000			2.180 ±	0.312	3.090 ±	0.000
	Range	3.880 -	3.880	2.000 -	2.000			2.000 -	2.540	3.090 -	3.090
Cd	n	19		68		3		40		15	
	Mean±Sd	1.274 ±	1.599	0.582 ±	0.699	0.230 ±	0.182	0.329 ±	0.577	0.561 ±	0.948
	Range	0.015 -	4.690	0.015 -	3.530	0.125 -	0.440	0.015 -	3.010	0.015 -	2.787
Cr	n	19		68		3		40		15	
	Mean±Sd	6.395 ±	15.873	3.192 ±	3.636	2.680 ±	1.590	2.123 ±	2.716	2.438 ±	3.728
	Range	0.180 -	70.370	0.040 -	13.900	1.320 -	4.428	0.025 -	13.700	0.260 -	14.800
Co	n	4		13		2		4		2	
	Mean±Sd	0.320 ±	0.000	0.320 ±	0.000	0.320 ±	0.000	0.320 ±	0.000	0.320 ±	0.000
	Range	0.320 -	0.320	0.320 -	0.320	0.320 -	0.320	0.320 -	0.320	0.320 -	0.320
Cu	n	19		68		3		40		15	
	Mean±Sd	164.176 ±	356.821	38.107 ±	44.723	26.045 ±	21.650	27.029 ±	76.403	242.857 ±	538.347
	Range	0.280 -	1466.610	0.400 -	197.600	3.109 -	46.125	0.400 -	408.350	1.400 -	2064.122
Fe	n	19		72		3		42		16	
	Mean±Sd	535.037 ±	787.765	1199.488 ±	2957.692	845.160 ±	861.779	213.273 ±	371.732	201.703 ±	210.204
	Range	0.480 -	2398.000	0.050 -	17570.910	109.620 -	1793.360	0.050 -	2299.400	0.210 -	738.200
Pb	n	4		13		2		4		2	
	Mean±Sd	0.620 ±	0.000	0.620 ±	0.000	0.620 ±	0.000	0.620 ±	0.000	0.620 ±	0.000
	Range	0.620 -	0.620	0.620 -	0.620	0.620 -	0.620	0.620 -	0.620	0.620 -	0.620
Mn	n	19		68		3		40		15	
	Mean±Sd	55.884 ±	154.570	10.939 ±	21.475	7.387 ±	0.791	7.537 ±	8.431	13.293 ±	13.794
	Range	0.850 -	680.180	0.289 -	150.960	6.600 -	8.181	0.418 -	40.800	1.310 -	41.020
Ni	n	19		68		3		40		15	
	Mean±Sd	4.738 ±	9.259	1.660 ±	2.104	0.976 ±	0.297	1.556 ±	1.392	1.598 ±	1.664
	Range	0.473 -	41.670	0.030 -	11.650	0.738 -	1.309	0.190 -	6.600	0.490 -	7.400
Zn	n	19		72		3		42		16	
	Mean±Sd	73.687 ±	38.711	93.138 ±	75.480	87.281 ±	41.778	69.022 ±	70.162	86.220 ±	73.497
	Range	3.110 -	159.750	1.800 -	290.770	39.709 -	118.000	2.480 -	409.247	12.680 -	212.800
DWF	n	10		43		1		23		4	
	Mean±Sd	0.232 ±	0.041	0.301 ±	0.190	0.227 ±	0.000	0.296 ±	0.164	0.295 ±	0.070
	Range	0.180 -	0.306	0.178 -	0.970	0.227 -	0.227	0.200 -	0.992	0.230 -	0.390

Appendix C6: cont.

		Crocodile							
		H.vittatus		*T.rendalli*		*L.congoro*		*L.rosae*	
Al	n	0		3		0		0	
	Mean±Sd			54.000 ±	31.000				
	Range			30.000 -	89.000				
As	n	0		3		1		0	
	Mean±Sd			2.000 ±	0.000	2.490 ±	0.000		
	Range			2.000 -	2.000	2.490 -	2.490		
Cd	n	3		19		10		1	
	Mean±Sd	0.310 ±	0.320	0.540 ±	0.691	1.849 ±	1.753	7.660 ±	0.000
	Range	0.125 -	0.680	0.015 -	2.010	0.200 -	5.810	7.660 -	7.660
Cr	n	3		19		10		1	
	Mean±Sd	2.970 ±	1.690	2.196 ±	2.768	3.678 ±	3.371	16.830 ±	0.000
	Range	1.693 -	4.886	0.120 -	8.300	1.000 -	9.320	16.830 -	16.830
Co	n	2		0		0		0	
	Mean±Sd	0.320 ±	0.000						
	Range	0.320 -	0.320						
Cu	n	3		19		10		1	
	Mean±Sd	23.075 ±	35.596	112.563 ±	195.353	246.596 ±	232.276	2195.060 ±	0.000
	Range	1.800 -	64.169	0.310 -	644.350	1.400 -	625.200	2195.060 -	2195.060
Fe	n	3		20		10		1	
	Mean±Sd	1703.360 ±	2880.649	176.712 ±	221.488	163.199 ±	255.944	1.950 ±	0.000
	Range	0.030 -	5029.320	0.160 -	750.000	0.170 -	791.000	1.950 -	1.950
Pb	n	2		0		0		0	
	Mean±Sd	0.620 ±	0.000						
	Range	0.620 -	0.620						
Mn	n	3		19		10		1	
	Mean±Sd	9.634 ±	6.409	12.586 ±	15.708	12.586 ±	10.553	208.670 ±	0.000
	Range	3.500 -	16.287	0.610 -	55.315	2.520 -	28.600	208.670 -	208.670
Ni	n	3		19		10		1	
	Mean±Sd	1.140 ±	0.505	3.163 ±	6.133	1.750 ±	1.884	6.150 ±	0.000
	Range	0.620 -	1.629	0.250 -	27.657	0.200 -	5.600	6.150 -	6.150
Zn	n	3		20		10		1	
	Mean±Sd	62.637 ±	71.388	101.063 ±	103.625	65.584 ±	41.178	135.790 ±	0.000
	Range	17.669 -	144.951	5.870 -	473.970	19.290 -	134.400	135.790 -	135.790
DWF	n	1		13		10		1	
	Mean±Sd	0.230 ±	0.000	0.274 ±	0.070	0.254 ±	0.063	0.220 ±	0.000
	Range	0.230 -	0.230	0.170 -	0.420	0.190 -	0.381	0.220 -	0.220

Appendix C6: cont.

		Letaba							
		O.mossambicus		*C.gariepinus*		*S.intermedius*		*B.marequensis*	
Al	n	9		5		2		0	
	Mean±Sd	234.616 ±	414.096	55.400 ±	35.347	52.500 ±	30.406		
	Range	41.000 -	1330.000	19.108 -	93.000	31.000 -	74.000		
Cd	n	30		21		6		4	
	Mean±Sd	0.610 ±	0.460	0.480 ±	0.634	0.835 ±	0.673	1.270 ±	2.182
	Range	0.040 -	1.770	0.030 -	2.880	0.350 -	1.918	0.070 -	4.540
Cr	n	30		21		6		4	
	Mean±Sd	2.620 ±	3.038	1.958 ±	2.260	2.440 ±	2.361	9.898 ±	3.177
	Range	0.279 -	10.730	0.441 -	9.270	0.481 -	6.400	6.400 -	14.100
Cu	n	30		21		6		4	
	Mean±Sd	472.501 ±	514.816	49.880 ±	39.213	54.854 ±	19.955	109.000 ±	191.249
	Range	0.800 -	2135.420	0.300 -	156.400	19.800 -	79.300	4.500 -	395.700
Fe	n	30		21		6		4	
	Mean±Sd	1563.864 ±	4230.846	3888.453 ±	8424.987	1108.569 ±	612.854	710.950 ±	533.874
	Range	45.700 -	21600.000	15.000 -	37900.000	620.100 -	2175.000	47.700 -	1355.000
Mg	n	5		1		2		2	
	Mean±Sd	4.894 ±	3.294	6.960 ±	0.000	2.375 ±	0.021	2.770 ±	2.404
	Range	0.650 -	8.520	6.960 -	6.960	2.360 -	2.390	1.070 -	4.470
Mn	n	25		19		4		2	
	Mean±Sd	16.166 ±	26.966	6.334 ±	4.615	5.791 ±	1.506	17.945 ±	12.240
	Range	1.200 -	135.520	2.000 -	18.810	3.700 -	7.033	9.290 -	26.600
Ni	n	21		16		4		4	
	Mean±Sd	2.173 ±	1.738	0.902 ±	1.190	1.008 ±	0.752	4.198 ±	2.642
	Range	0.500 -	6.270	0.050 -	4.000	0.400 -	2.010	2.100 -	7.640
Zn	n	30		21		6		4	
	Mean±Sd	79.276 ±	37.933	97.281 ±	49.322	136.001 ±	49.279	96.103 ±	46.054
	Range	2.000 -	165.240	1.000 -	209.500	80.500 -	219.300	49.700 -	155.900
DWF	n	30		21		6		4	
	Mean±Sd	0.346 ±	0.169	0.298 ±	0.174	0.232 ±	0.029	0.242 ±	0.022
	Range	0.183 -	0.950	0.132 -	0.960	0.186 -	0.274	0.215 -	0.260

Appendix C6: cont.

		Letaba			
		L.rosae		*L.ruddi*	
Al	n	5		1	
	Mean±Sd	2169.480 ±	4259.555	120.690 ±	0.000
	Range	125.000 -	9782.016	120.690 -	120.690
Cd	n	5		1	
	Mean±Sd	1.449 ±	0.724	0.100 ±	0.000
	Range	0.491 -	2.427	0.100 -	0.100
Cr	n	5		1	
	Mean±Sd	15.311 ±	29.368	0.500 ±	0.000
	Range	0.427 -	67.711	0.500 -	0.500
Co	n	1		0	
	Mean±Sd	9.591 ±	0.000		
	Range	9.591 -	9.591		
Cu	n	5		1	
	Mean±Sd	752.151 ±	580.035	224.138 ±	0.000
	Range	30.109 -	1405.983	224.138 -	224.138
Fe	n	5		1	
	Mean±Sd	1051.697 ±	629.458	5545.959 ±	0.000
	Range	507.062 -	2128.978	5545.959 -	5545.959
Pb	n	1		0	
	Mean±Sd	3.406 ±	0.000		
	Range	3.406 -	3.406		
Mn	n	5		1	
	Mean±Sd	82.844 ±	145.852	19.073 ±	0.000
	Range	6.063 -	341.458	19.073 -	19.073
Zn	n	5		1	
	Mean±Sd	99.648 ±	36.598	166.379 ±	0.000
	Range	54.019 -	147.990	166.379 -	166.379
DWF	n	5		1	
	Mean±Sd	0.326 ±	0.063	0.235 ±	0.000
	Range	0.251 -	0.409	0.235 -	0.235

Appendix C6: cont.

		Levuvhu											
		O.mossambicus		*C.gariepinus*		*B.marequensis*		*H.vittatus*		*L.congoro*		*L.rosae*	
Cu	n	6		16		5		2		5		2	
	Mean±Sd	116.055 ±	168.485	55.970 ±	51.809	34.481 ±	58.720	36.898 ±	48.642	895.416 ±	1246.633	437.798 ±	606.422
	Range	5.027 -	348.264	4.004 -	155.934	3.003 -	138.980	2.503 -	71.293	4.518 -	2881.016	8.993 -	866.603
Fe	n	6		16		5		2		5		2	
	Mean±Sd	684.354 ±	480.389	1482.320 ±	1214.252	438.480 ±	221.492	1295.813 ±	1709.074	480.387 ±	318.429	522.627 ±	115.937
	Range	213.678 -	1540.123	136.513 -	3864.068	179.356 -	745.733	87.315 -	2504.310	200.274 -	1014.745	440.647 -	604.607
Mn	n	6		16		5		2		5		2	
	Mean±Sd	55.655 ±	43.557	18.560 ±	15.637	15.730 ±	11.895	11.188 ±	8.995	33.651 ±	27.247	35.973 ±	40.694
	Range	10.934 -	133.312	3.317 -	49.547	3.689 -	29.805	4.828 -	17.548	4.011 -	66.423	7.198 -	64.748
Zn	n	6		16		5		2		5		2	
	Mean±Sd	200.025 ±	175.195	216.258 ±	112.258	88.267 ±	43.071	239.178 ±	197.873	252.885 ±	142.494	203.878 ±	49.457
	Range	50.556 -	451.005	60.786 -	381.724	60.961 -	161.892	99.261 -	379.095	84.893 -	376.323	168.906 -	238.849
DWF	n	6		16		5		2		5		2	
	Mean±Sd	0.306 ±	0.013	0.297 ±	0.053	0.279 ±	0.029	0.309 ±	0.056	0.289 ±	0.023	0.294 ±	0.009
	Range	0.293 -	0.323	0.223 -	0.410	0.236 -	0.304	0.269 -	0.348	0.258 -	0.319	0.287 -	0.300

Appendix C6: cont.

		Olifants							
		O.mossambicus		*C.gariepinus*		*B.marequensis*		*L.congoro*	
Al	n	10		38		2		9	
	Mean±Sd	175.486 ±	192.747	209.403 ±	248.226	159.432 ±	10.511	282.313 ±	174.261
	Range	33.465 -	638.797	7.785 -	1080.000	152.000 -	166.865	43.342 -	503.000
Cd	n	9		20		0		7	
	Mean±Sd	0.276 ±	0.315	0.604 ±	0.492			4.299 ±	4.304
	Range	0.050 -	0.945	0.050 -	1.563			0.100 -	10.867
Cr	n	10		38		2		9	
	Mean±Sd	1.087 ±	0.532	1.932 ±	1.509	1.589 ±	0.356	2.522 ±	1.570
	Range	0.500 -	1.762	0.300 -	5.550	1.337 -	1.841	0.500 -	4.157
Co	n	9		32		1		7	
	Mean±Sd	4.939 ±	4.339	6.836 ±	12.109	2.197 ±	0.000	1.389 ±	0.498
	Range	0.786 -	12.402	0.100 -	49.540	2.197 -	2.197	0.534 -	1.931
Cu	n	10		31		2		9	
	Mean±Sd	1807.522 ±	2489.758	32.998 ±	34.193	57.820 ±	41.123	543.019 ±	641.759
	Range	22.714 -	6802.100	3.979 -	125.000	28.741 -	86.898	12.974 -	1938.889
Fe	n	10		38		2		9	
	Mean±Sd	764.566 ±	537.678	991.829 ±	944.953	664.895 ±	178.022	559.528 ±	288.963
	Range	200.993 -	1657.415	82.890 -	3971.774	539.014 -	790.775	205.748 -	1193.423
Pb	n	10		31		2		9	
	Mean±Sd	7.989 ±	18.819	1.959 ±	4.671	2.472 ±	2.551	1.663 ±	3.752
	Range	0.400 -	61.069	0.360 -	22.123	0.668 -	4.276	0.400 -	11.667
Mn	n	10		38		2		9	
	Mean±Sd	26.548 ±	31.535	15.169 ±	18.748	10.765 ±	5.771	20.488 ±	22.577
	Range	6.759 -	104.819	0.042 -	73.113	6.685 -	14.846	2.827 -	59.880
Zn	n	10		38		2		9	
	Mean±Sd	101.482 ±	107.844	142.999 ±	69.964	180.405 ±	74.573	212.705 ±	164.561
	Range	46.480 -	406.011	8.820 -	428.274	127.674 -	233.135	72.864 -	510.602
DWF	n	10		38		2		9	
	Mean±Sd	0.316 ±	0.037	0.274 ±	0.120	0.264 ±	0.015	0.307 ±	0.050
	Range	0.273 -	0.373	0.145 -	0.895	0.253 -	0.274	0.237 -	0.393

Appendix C6: cont.

		Olifants					
		L.rosae		*L.ruddi*		*H.molitrix*	
Al	n	2		6		1	
	Mean±Sd	706.098±	495.742	85.451±	116.775	40.984±	0.000
	Range	355.556-	1056.641	7.711-	310.930	40.984-	40.984
Cd	n	2		6		1	
	Mean±Sd	2.564±	3.143	0.331±	0.262	0.373±	0.000
	Range	0.342-	4.786	0.100-	0.687	0.373-	0.373
Cr	n	2		6		1	
	Mean±Sd	3.733±	1.067	2.803±	2.529	1.751±	0.000
	Range	2.979-	4.487	0.500-	5.416	1.751-	1.751
Co	n	2		6		1	
	Mean±Sd	3.031±	0.488	0.420±	0.550	2.049±	0.000
	Range	2.686-	3.376	0.100-	1.435	2.049-	2.049
Cu	n	2		6		1	
	Mean±Sd	27.979±	2.556	1220.275±	1483.016	222.355±	0.000
	Range	26.172-	29.786	4.989-	3662.541	222.355-	222.355
Fe	n	2		6		1	
	Mean±Sd	4639.223±	178.760	218.267±	111.322	1719.449±	0.000
	Range	4512.821-	4765.625	111.932-	416.332	1719.449-	1719.449
Pb	n	2		6		1	
	Mean±Sd	454.712±	600.178	0.400±	0.000	0.600±	0.000
	Range	30.322-	879.103	0.400-	0.400	0.600-	0.600
Mn	n	2		6		1	
	Mean±Sd	34.325±	32.527	46.744±	53.546	7.414±	0.000
	Range	11.325-	57.324	6.696-	142.870	7.414-	7.414
Zn	n	2		6		1	
	Mean±Sd	524.289±	356.070	258.216±	148.291	242.586±	0.000
	Range	272.510-	776.068	107.873-	509.799	242.586-	242.586
DWF	n	2		6		1	
	Mean±Sd	0.239±	0.021	0.288±	0.037	0.228±	0.000
	Range	0.224-	0.253	0.244-	0.340	0.228-	0.228

Appendix C6: cont.

		Sabie							
		O.mossambicus		*C.gariepinus*		*S.intermedius*		*B.marequensis*	
Al	n	2		4		3		7	
	Mean±Sd	124.594 ±	140.897	85.650 ±	43.296	45.268 ±	60.393	106.279 ±	150.079
	Range	24.964 -	224.223	20.833 -	111.000	9.804 -	115.000	5.000 -	441.652
Cd	n	2		4		3		7	
	Mean±Sd	0.385 ±	0.404	0.988 ±	1.288	0.831 ±	0.184	0.654 ±	0.452
	Range	0.100 -	0.671	0.100 -	2.831	0.691 -	1.040	0.100 -	1.330
Fe	n	2		4		3		7	
	Mean±Sd	1869.737 ±	265.917	2200.461 ±	1942.919	1156.231 ±	709.744	767.035 ±	521.366
	Range	1681.705 -	2057.768	187.734 -	4175.548	555.000 -	1939.161	278.358 -	1688.177
Mn	n	2		4		3		7	
	Mean±Sd	15.483 ±	2.024	16.356 ±	20.972	7.510 ±	4.264	11.139 ±	8.780
	Range	14.051 -	16.914	3.850 -	47.661	4.902 -	12.431	5.319 -	30.700
Zn	n	2		3		1		6	
	Mean±Sd	56.964 ±	12.445	138.029 ±	34.678	123.802 ±	0.000	105.768 ±	14.991
	Range	48.164 -	65.763	112.786 -	177.570	123.802 -	123.802	88.779 -	130.720
DWF	n	2		4		3		7	
	Mean±Sd	0.334 ±	0.014	0.272 ±	0.046	0.230 ±	0.015	0.241 ±	0.018
	Range	0.324 -	0.344	0.248 -	0.342	0.215 -	0.245	0.218 -	0.277

Appendix C6: cont.

		Sabie					
		H.vittatus		*L.congoro*		*L.rosae*	
Al	n	2		8		7	
	Mean±Sd	22.988 ±	21.435	90.664 ±	60.074	87.743 ±	105.970
	Range	7.831 -	38.144	9.000 -	174.218	12.000 -	312.362
Cd	n	2		8		7	
	Mean±Sd	0.100 ±	0.000	0.677 ±	0.206	1.593 ±	0.866
	Range	0.100 -	0.100	0.472 -	1.048	0.525 -	3.256
Fe	n	2		8		7	
	Mean±Sd	2352.684 ±	1196.838	258.464 ±	34.212	328.179 ±	78.157
	Range	1506.392 -	3198.976	185.294 -	298.881	171.491 -	405.808
Mn	n	2		8		7	
	Mean±Sd	5.924 ±	0.370	16.258 ±	21.438	6.832 ±	2.497
	Range	5.663 -	6.186	2.095 -	51.726	3.811 -	10.596
Zn	n	2		6		5	
	Mean±Sd	136.464 ±	25.106	124.131 ±	116.699	110.123 ±	26.196
	Range	118.711 -	154.217	38.471 -	285.728	79.650 -	138.024
DWF	n	2		8		7	
	Mean±Sd	0.259 ±	0.006	0.371 ±	0.088	0.282 ±	0.056
	Range	0.255 -	0.263	0.249 -	0.530	0.237 -	0.388

Appendix C
Metal Bioaccumulation Data

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	BHC	Dieldrin	Lindane	DDE	DDD	DDT	Heptachlor	Endosulfan	Mercapthion	Diazinon	Pirimiphos	Aldrin	Endrin	Atrazine
Oct-92	BER	MISVERST	Om	EGGS	230	400	2	6		0.0005	0.01	0.0005	0.013	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.11
Oct-92	BER	MISVERST	Om	FAT	215	259	2	5		0.0005	0.028	0.0005	0.013	0.01	0.007	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.82
Oct-92	BER	MISVERST	Om	FAT	285.5	422.5	1	5		0.0005	0.031	0.0005	0.078	0.05	0.019	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.1
Oct-92	BER	VOELVLEI	Cc	TESTES	510	3750	1	6	8	0.0005	0.002	0.0005	0.016	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.03
Oct-92	BER	VOELVLEI	Cc	EGGS	420	2500	2	5	4	0.0005	0.011	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.07
Oct-92	BER	VOELVLEI	Cc	FAT	420	2500	2	5	4	0.0005	0.028	0.0005	0.088	0.027	0.008	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-92	BER	VOELVLEI	Cc	TESTES	455	3000	1	6	8	0.0005	0.15	0.0005	0.014	0.018	0.048	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.04
Oct-93	BER	VOELVLEI	Cc	TESTES	470	2850	1	6	3	0.0005	0.021	0.0005	0.008	0.008	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.04
Jan-88	CRO	HNGEL_CL	Lm	LIVER						0.0005	1.517	0.0005	0.169	0.005	0.005	0.005	5.57	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	HNGEL_CL	Lm	FLESH						0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	HNGEL_CL	Lm	EGGS						0.0005	0.242	0.0005	0.005	0.005	0.005	0.005	0.267	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	MATAFFIN	Bm	GUT						0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	MATAFFIN	Bm	LIVER						0.0005	0.059	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	MATAFFIN	Bm	FLESH						0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	RVERSIDE	Bm	LIVER						0.074	0.151	0.0005	4.623	1.987	0.844	0.005	3.753	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	RVERSIDE	Bm	EGGS						0.0005	0.088	0.0005	0.893	0.252	0.064	0.005	0.387	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	RVERSIDE	Lm	LIVER						0.0005	1.27	0.0005	0.005	0.005	0.005	0.005	0.56	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	RVERSIDE	Bm	FLESH						0.005	0.047	0.008	0.071	0.07	0.005	0.005	0.348	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	RVERSIDE	Lm	EGGS						0.0005	1.18	0.0005	0.005	0.005	0.24	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	RVERSIDE	Lm	FAT						0.0005	11.59	0.0005	0.005	2.3	0.53	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	RVERSIDE	Lm	FLESH						0.0005	0.27	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	RVERSIDE	Lm	GUT						0.0005	12.27	0.0005	0.005	0.005	0.005	0.005	3.499	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	TENBOSCH	Hv	FLESH						0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	TENBOSCH	Hv	LIVER						0.048	2.22	0.085	0.054	1.04	0.224	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-88	CRO	TENBOSCH	Hv	GUT						0.0005	3.12	0.0005	0.068	1.12	3.456	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	MATAFFIN	C	EGGS						0.004	0.032	0.004	0.083	0.717	0.005	0.005	1.073	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	MATAFFIN	Lm	EGGS						0.0005	0.037	0.0005	0.4	0.005	0.005	0.005	2.485	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	MATAFFIN	C	LIVER						0.0005	0.049	0.0005	0.372	1.815	0.005	0.005	1.336	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	MATAFFIN	Lm	LIVER						0.018	0.078	0.0005	0.497	0.433	0.005	0.016	7.354	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	MATAFFIN	Lm	FLESH						0.0005	0.039	0.0005	0.005	0.005	0.005	0.005	0.594	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	MATAFFIN	C	FLESH						0.0005	0.077	0.004	0.005	0.853	0.005	0.005	1.073	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	MONTROSE	C	FLESH						0.0005	0.033	0.0005	0.099	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	MONTROSE	C	LIVER						0.0005	0.057	0.0005	0.147	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	RVERSIDE	Lr	LIVER						0.0005	0.045	0.0005	1.096	0.31	0.005	0.005	0.06	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	TENBOSCH	Om	LIVER						0.033	0.071	0.098	0.153	0.432	0.096	0.005	0.165	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	TENBOSCH	Lr	FLESH						0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	TENBOSCH	Lr	EGGS						0.0005	0.042	0.006	0.386	0.005	0.062	0.005	0.285	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	TENBOSCH	Om	FLESH						0.0005	0.005	0.12	0.005	0.005	0.005	0.005	0.63	0.005	0.005	0.005	0.005	0.005	0.0005
May-88	CRO	TENBOSCH	Lr	LIVER						0.0005	0.034	0.0005	0.368	0.005	0.005	0.045	0.513	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	CROC_HOT	Lm	FLESH	306	730	1	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	CROC_HOT	Bm	LIVER	311.5	787.5	1.5	4.5		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	CROC_HOT	Bm	FLESH	320	855	2	5		0.0005	0.005	0.0005	0.02	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Bm	FLESH	221.6	257.3	1	3.5		0.0005	0.01	0.0005	0.01	0.005	0.005	0.005	0.005	0.005	0.03	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Bm	FLESH	334	900	2	3		0.0005	0.005	0.0005	0.01	0.005	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	C	FLESH	390	620	1	1		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.02	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Bm	EGGS	400	1800	2	4		0.0005	0.05	0.0005	0.24	0.005	0.005	0.005	0.005	0.005	0.04	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	C	FLESH	308	314	1.5	1.5		0.0005	0.005	0.0005	0.01	0.005	0.005	0.005	0.005	0.005	0.03	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Bm	FAT	221.6	257.3	1	3.5		0.0005	0.85	0.0005	1.59	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	BHC	Dieldrin	Lindane	DDE	DDD	DDT	Heptachlor	Endosulfan	Mercapthion	Diazinon	Pirimiphos	Aldrin	Endrin	Atrazine
Sep-89	CRO	HNGEL_CL	C	FLESH	560.7	1815	1	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.01	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Bm	FLESH	400	1800	2	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.03	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	C	FLESH	390	620	1	1		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.04	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Lm	FLESH	376	1800	2	5		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.02	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Bm	FAT	367	1350	2	3.5		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.06	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Bm	LIVER	400	1800	2	4		0.0005	0.03	0.0005	0.1	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	C	LIVER	291	260	2	1		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.04	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	C	LIVER	330	340	2	1		0.0005	0.005	0.0005	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Bm	LIVER	334	900	2	3		0.0005	0.02	0.0005	0.19	0.005	0.005	0.005	0.005	0.005	0.04	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	Bm	LIVER	214	260	1	3		0.0005	0.005	0.0005	0.13	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	HNGEL_CL	C	LIVER	390	620	1	1		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	LIONS_CL	C	FLESH	645	2640	1	4		0.0005	0.06	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.05	0.005	0.005	0.005	0.0005
Sep-89	CRO	LIONS_CL	Om	FLESH	235	480	2	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.02	0.005	0.005	0.005	0.0005
Sep-89	CRO	LIONS_CL	Lm	FLESH	290	650	2	4		0.0005	0.01	0.0005	0.02	0.005	0.005	0.005	0.005	0.005	0.02	0.005	0.005	0.005	0.0005
Sep-89	CRO	LIONS_CL	C	LIVER	645	2640	1	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.03	0.005	0.005	0.005	0.0005
Sep-89	CRO	LIONS_CL	C	FLESH	525	1600	1	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.02	0.005	0.005	0.005	0.0005
Sep-89	CRO	LIONS_CL	Bm	FLESH	366	1250	2	5		0.0005	0.04	0.0005	0.04	0.005	0.005	0.005	0.005	0.005	0.07	0.005	0.005	0.005	0.0005
Sep-89	CRO	LIONS_CL	C	TESTES	585	2120	1	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.02	0.005	0.005	0.005	0.0005
Sep-89	CRO	RVERSIDE	Lm	EGGS	376	1680	2	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.09	0.04	0.005	0.005	0.005	0.0005
Sep-89	CRO	RVERSIDE	Lm	FLESH	376	1680	2	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.04	0.005	0.005	0.005	0.0005
Sep-89	CRO	RVERSIDE	Lm	LIVER	376	1680	2	4		0.0005	0.37	0.0005	0.76	0.005	0.005	0.005	0.005	0.06	0.08	0.09	0.005	0.005	0.0005
Sep-89	CRO	RVERSIDE	Bm	FLESH	340	1000	2	5		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	RVERSIDE	C	LIVER	525	1760	2	2		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	RVERSIDE	C	EGGS	475	1380	2	5		0.0005	0.005	0.0005	0.04	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	RVERSIDE	Tr	FLESH	246	660	1	5		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.1	0.04	0.005	0.005	0.005	0.0005
Sep-89	CRO	RVERSIDE	C	FLESH	525	1760	2	2		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.1	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Tr	FLESH	315	1440	2	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.06	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	C	LIVER	655	3260	1	5		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Om	FAT	302.5	1040	1.5	5		0.0005	0.04	0.0005	0.83	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Om	EGGS	295	880	2	5		0.0005	0.4	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	C	FLESH	655	3260	1	5		0.0005	0.01	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.05	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	C	EGGS	590	2450	1	5		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.04	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Tr	FAT	282	1040	1.7	4		0.0005	0.005	0.0005	0.1	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Tr	EGGS	315	1440	2	4		0.0005	0.01	0.0005	0.05	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Tr	LIVER	295	1160	1.5	4		0.0005	0.4	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Om	LIVER	297	980	1.7	4.7		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Om	TESTES	310	1200	1	5		0.0005	0.01	0.0005	0.003	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Om	FLESH	310	1200	1	5		0.0005	0.05	0.0005	0.001	0.005	0.005	0.005	0.005	0.005	0.06	0.005	0.005	0.005	0.0005
Sep-89	CRO	TENBOSCH	Tr	TESTES	275	880	1	4		0.0005	0.005	0.0005	0.05	0.005	0.09	0.005	0.005	0.005	0.12	0.005	0.005	0.005	0.0005
Jan-90	CRO	CROC_HOT	Bm	EGGS	327	985	2	5	2	0.0005	0.007	0.0005	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	HNGEL_CL	C	EGGS	393	690	2	5	2	0.0005	0.007	0.0005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	LIONS_CL	C	FAT	535	2720	1	4	3	0.0005	0.003	0.0005	0.06	0.005	0.005	0.005	0.005	0.005	0.06	0.09	0.005	0.005	0.0005
Jan-90	CRO	LIONS_CL	C	EGGS	475	1350	2	4	2	0.0005	0.008	0.0005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	MATAFFIN	Lm	EGGS	366	1180	2	4		0.0005	0.005	0.0005	0.002	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	MATAFFIN	Bm	EGGS	319	800	2	4	2	0.0005	0.007	0.0005	0.004	0.005	0.005	0.005	0.03	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	MATAFFIN	C	TESTES	665	2930	1	5	3	0.0005	0.004	0.0005	0.001	0.005	0.005	0.005	0.009	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	MATAFFIN	C	LIVER	665	2930	1	5	3	0.0005	0.006	0.0005	0.007	0.005	0.005	0.005	0.03	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	MATAFFIN	C	FAT	665	2930	1	5	3	0.0005	0.007	0.0005	0.03	0.005	0.01	0.005	0.005	0.005	0.09	0.09	0.005	0.005	0.0005

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	BHC	Dieldrin	Lindane	DDE	DDD	DDT	Heptachlor	Endosulfan	Mercapthion	Diazinon	Pirimiphos	Aldrin	Endrin	Atrazine
Jan-90	CRO	RVERSIDE	C	EGGS	435	1100	2	4	3	0.0005	0.0004	0.0005	0.006	0.005	0.01	0.005	0.003	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	TENBOSCH	Tr	FAT	251.5	745	2	4		0.0005	0.01	0.0005	0.002	0.005	0.005	0.005	0.006	0.005	0.2	0.43	0.005	0.005	0.0005
Jan-90	CRO	TENBOSCH	Om	FAT	292	1400	1	3	2	0.0005	0.03	0.0005	0.008	0.005	0.005	0.005	0.005	0.005	0.08	0.12	0.005	0.005	0.0005
Jan-90	CRO	TENBOSCH	Tr	FAT	305	1400	1	4	3	0.0005	0.008	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.05	0.005	0.005	0.005	0.0005
Jan-90	CRO	TENBOSCH	Om	FLESH	292	1400	1	3	2	0.0005	0.001	0.0005	0.0008	0.005	0.005	0.005	0.001	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	TENBOSCH	Om	EGGS	278	740	2	5	4	0.0005	0.007	0.0005	0.008	0.005	0.012	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	TENBOSCH	Tr	EGGS	251.5	745	2	4		0.0005	0.009	0.0005	0.002	0.005	0.005	0.005	0.007	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-90	CRO	TENBOSCH	Om	LIVER	287	970	1.3	4		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	CROC_HOT	C	FAT	496.5	1580	1.5	4		0.0005	0.07	0.0005	0.25	0.06	0.13	0.005	0.03	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	CROC_HOT	Lm	EGGS	313	960	2	5	2	0.0005	0.03	0.0005	0.03	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	CROC_HOT	C	EGGS	550	2010	2	5	2	0.0005	0.04	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	HNGEL_CL	C	EGGS	474	1170	2	4	4	0.0005	0.05	0.0005	0.05	0.02	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	LIONS_CL	Bm	EGGS	307	1510	2	4		0.0005	0.05	0.0005	0.07	0.005	0.005	0.005	0.04	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	MATAFFIN	C	FAT	512	2800	1	5	2	0.0005	0.11	0.0005	0.35	0.05	0.06	0.005	0.08	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	MATAFFIN	Bm	EGGS	350	1120	2	4		0.0005	0.03	0.0005	0.05	0.005	0.005	0.005	0.08	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	RVERSIDE	Sz	EGGS	295	200	2	5		0.0005	0.01	0.0005	0.04	0.02	0.02	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	RVULETTS	C	EGGS	655	3200	2	5	4	0.0005	0.005	0.0005	0.05	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	TENBOSCH	Lc	FLESH	395	1480	2	2	3	0.0005	0.02	0.0005	0.03	0.005	0.005	0.005	0.03	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-90	CRO	TENBOSCH	Tr	EGGS	288	760	2	4	3	0.0005	0.04	0.0005	0.06	0.03	0.04	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-90	CRO	MATAFFIN	C	LIVER	430	910	1	1		0.0005	0.4	0.0005	0.54	0.46	0.39	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-90	CRO	MATAFFIN	Bm	FAT	285	440	2	1		0.0005	0.36	0.0005	2.6	0.81	0.83	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-90	CRO	MATAFFIN	C	FAT	472	910	1	4		0.0005	0.38	0.0005	2.81	1.7	1.27	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-90	CRO	HNGEL_CL	Bm	FAT	267	413.3	2	4		0.0005	0.35	0.0005	0.54	0.4	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-90	CRO	HNGEL_CL	C	FAT	432	1000	2	2		0.0005	0.39	0.0005	0.8	0.47	0.31	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-90	CRO	LIONS_CL	C	LIVER	841	7250	1	3		0.0005	0.41	0.0005	0.6	0.43	0.41	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-90	CRO	LIONS_CL	C	FAT	841	7250	1	3		0.0005	0.48	0.0005	2.1	0.55	0.33	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-90	CRO	RVERSIDE	C	LIVER	457	1260	2	2	4	0 0005	0.39	0.0005	0.38	0.39	0.4	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-90	CRO	TENBOSCH	Tr	FAT	261.5	975	1	4		0.0005	0.41	0.0005	0.53	0.4	0.28	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-90	CRO	TENBOSCH	Om	GUT	232	550	2	2	4	0.0005	0.42	0.0005	0.18	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.58	0.005	0.0005
Jun-90	CRO	TENBOSCH	Lc	EGGS	389	2025	2	6		0.0005	0.16	0.0005	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	CROC_HOT	C	TESTES	539	1868				0.0005	0.15	0.0005	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	CROC_HOT	Bm	EGGS	339.5	1350			2.5	0.0005	0.16	0.0005	0.16	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	CROC_HOT	C	EGGS	600	2350			2	0.0005	0.16	0.0005	0.17	0.15	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	CROC_HOT	C	LIVER	532	1808				0.22	0.16	0.02	0.19	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	HNGEL_CL	C	FAT	618	2950				0.21	0.16	0.02	0.43	0.34	0.4	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	LIONS_CL	Lm	TESTES	287.3	637.5				0.0005	0.16	0.0005	0.18	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	LIONS_CL	C	EGGS	482	1325			3	0.0005	0.16	0.02	0.19	0.18	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	LIONS_CL	C	FAT	867	7550			8	0.25	0.26	0.03	3.15	0.69	0.71	0.005	0.005	0 005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	RVERSIDE	Bm	TESTES	237	350			2	0.21	0.16	0.02	0.17	0.16	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	RVERSIDE	Lm	TESTES	256	525			3	0.0005	0.16	0.0005	0.16	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	RVERSIDE	Bi	EGGS	185	185				0.0005	0.17	0.0005	0.17	0.2	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	RVERSIDE	Lc	EGGS	330	1075			2	0.21	0.16	0.0005	0.19	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	RVERSIDE	Lm	EGGS	275.5	637.5				0.06	0 17	0.0005	0.22	0.16	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	RVERSIDE	Lc	TESTES	263	575				0 16	0.16	0.02	0.18	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	RVERSIDE	Bm	EGGS	256	475			2	0.17	0.16	0.0005	0.17	0.16	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	RVERSIDE	Sd	EGGS	239.5	235				0.0005	0.16	0.0005	0.18	0.17	0.16	0.005	0.005	0 005	0 005	0.005	0.005	0.005	0.0005
Oct-90	CRO	RVULETTS	C	EGGS	583.5	2200				0 0005	0.15	0 0005	0.17	0.16	0 005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0 0005
Oct-90	CRO	RVULETTS	C	TESTES	609.6	2408				0 0005	0.16	0.0005	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	BHC	Dieldrin	Lindane	DDE	DDD	DDT	Heptachlor	Endosulfan	Mercapthion	Diazinon	Pirimiphos	Aldrin	Endrin	Atrazine
Oct-90	CRO	RVULETTS	Lm	EGGS	328	1000				0.0005	0.22	0.0005	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	TENBOSCH	Tr	EGGS	265	900				0.0005	0.16	0.0005	0.16	0.16	0.14	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	TENBOSCH	Om	EGGS	259	762.5				0.0005	0.18	0.0005	0.18	0.17	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	TENBOSCH	Lc	EGGS	441	2080			2.5	0.0005	0.16	0.0005	0.15	0.17	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	CRO	TENBOSCH	Tr	FAT	280	1280				0.0005	0.27	0.0005	0.18	0.31	0.23	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-91	CRO	HNGEL_CL	Bm	EGGS	277	480	2	5	2	0.0005	0.18	0.0005	0.18	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-91	CRO	HNGEL_CL	Bm	FAT	204	170	2	2		0.0005	0.26	0.0005	0.73	0.16	0.32	0.005	5.11	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-91	CRO	HNGEL_CL	C	FAT	498	1410	1	4	2	0.0005	0.28	0.0005	0.65	0.25	0.61	0.005	3.33	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-91	CRO	HNGEL_CL	Lm	TESTES	304	770	1	5	3	0.0005	0.18	0.0005	0.24	0.005	0.55	0.005	0.5	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-91	CRO	HNGEL_CL	Lm	GUT	304	770	1	5	3	0.0005	0.21	0.0005	0.48	0.17	0.43	0.005	2.03	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-91	CRO	TENBOSCH	Lc	TESTES	378	1350	1	5	5	0.0005	0.24	0.0005	0.23	0.005	0.18	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-91	CRO	TENBOSCH	Lc	EGGS	356	1300	2	5	5	0.0005	0.18	0.0005	0.21	0.005	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-91	CRO	TENBOSCH	Tr	FAT	276	980	1	4	3	0.0005	0.25	0.0005	0.42	0.26	0.6	0.005	0.81	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-91	CRO	TENBOSCH	Hv	EGGS	277	480	2	5		0.0005	0.17	0.0005	0.18	0.005	0.19	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	CROC_HOT	Bm	GUT	230	255	1	1	2	0.0005	0.04	0.0005	0.11	0.03	0.04	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	HNGEL_CL	C	EGGS	548	1700	2	2	3	0.0005	0.02	0.0005	0.07	0.033	0.03	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	HNGEL_CL	C	FAT	548	1700	2	2	3	0.0005	0.03	0.0005	0.95	0.17	0.24	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	HNGEL_CL	Lm	EGGS	297	650	2	4	2	0.0005	0.02	0.0005	0.03	0.005	0.015	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	HNGEL_CL	Bm	EGG&FAT	257	450	2	4	2	0.0005	0.05	0.0005	0.6	0.14	0.07	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	LIONS_CL	Lm	GUT	270	440	2	2		0.0005	0.02	0.0005	0.24	0.04	0.03	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	MATAFFIN	Bm	GUT	281	650	2	2	3	0.0005	0.04	0.0005	0.14	0.04	0.04	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	RVERSIDE	Lr	GUT	281	620	2	1	3	0.0005	0.004	0.0005	0.07	0.17	0.18	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	RVERSIDE	Bm	TESTES	303	960	1	6		0.0005	0.03	0.0005	0.13	0.03	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	RVERSIDE	Lc	TESTES	274	680	1	2		0.0005	0.03	0.0005	0.35	0.09	0.21	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	RVERSIDE	Bm	FAT	344	1100	2	5	4	0.0005	0.004	0.0005	0.84	0.08	0.12	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	RVERSIDE	Bm	EGGS	344	1100	2	5	4	0.0005	0.01	0.0005	0.31	0.128	0.04	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	TENBOSCH	Om	GUT	299	1120	2	3	6	0.0005	0.02	0.0005	0.03	0.02	0.04	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	TENBOSCH	Om	EGGS	254	800	1	3	5	0.0005	0.03	0.0005	0.04	0.033	0.13	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	TENBOSCH	Hv	FAT	345	1060	2	2		0.0005	0.06	0.0005	1.13	0.58	0.79	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Mar-91	CRO	TENBOSCH	Lr	GUT	327	800	1	3	3	0.0005	0.01	0.0005	0.09	0.02	0.05	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	CROC_HOT	Bm	EGGS	360	1200	2	5	3	0.0005	0.206	0.0005	0.47	5.367	3.499	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	CROC_HOT	Bm	FAT	360	1200	2	5	3	0.0005	0.027	0.0005	0.048	0.047	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	LIONS_CL	Bm	TESTES	251.5	430	1	6		0.0005	0.025	0.0005	0.007	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	LIONS_CL	Bm	FAT	266	520	1	4		0.0005	0.005	0.0005	0.015	0.067	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	MATAFFIN	Bm	TESTES	267	490	1	5		0.0005	0.005	0.0005	0.014	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	MATAFFIN	Bm	FAT	284	600	1	5.5		0.0005	0.005	0.0005	0.022	0.044	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	RVERSIDE	Lm	TESTES	295	635	1	4.5		0.0005	0.006	0.0005	0.021	0.029	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	TENBOSCH	Tr	EGGS	244	750	2	3		0.0005	0.005	0.0005	0.009	0.032	0.022	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	TENBOSCH	Tr	FAT	233	810	2	3		0.0005	0.018	0.0005	0.031	0.02	0.002	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	TENBOSCH	Om	FAT	282	913.3	1.7	4		0.0005	0.054	0.0005	0.034	0.076	0.212	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	TENBOSCH	Om	EGGS	265	850	2	4	4	0.0005	0.011	0.002	0.005	0.026	0.019	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	TENBOSCH	Tr	FAT	233	810	2	3		0.0005	0.006	0.0005	0.012	0.097	0.074	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-91	CRO	TENBOSCH	Om	FAT	265	850	2	4		0.0005	0.028	0.0005	0.043	0.043	0.054	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-92	CRO	LIONS_CL	C	EGGS	470	1200	2	3	5	0.0005	0.02	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-92	CRO	LIONS_CL	C	EGGS	420	1000	2	2	3	0.0005	0.01	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-92	CRO	MATAFFIN	C	FAT	620	3000	2	2	2	0.0005	0.96	0.0005	0.95	0.32	0.02	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-92	CRO	MATAFFIN	C	EGGS	620	3000	2	2	2	0.0005	0.1	0.0005	0.01	0.01	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-92	CRO	RVULETTS	Bm	EGGS	456	2700	2	5	5	0.0005	0.007	0.0005	0.008	0.007	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	BHC	Dieldrin	Lindane	DDE	DDD	DDT	Heptachlor	Endosulfan	Mercapthion	Diazinon	Pirimiphos	Aldrin	Endrin	Atrazine
Sep-92	CRO	RVULETTS	Bm	EGGS	456	2700	2	5	5	0.0005	0.01	0.0005	0 07	0 01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-92	CRO	TENBOSCH	Tr	EGGS	247.5	714	2	2		0.0005	0.01	0.0005	0.04	0.03	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Sep-92	CRO	TENBOSCH	Tr	FAT	270	1024	1	4		0.0005	0.03	0.0005	0.14	0.08	0.06	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-90	LET	JUNCTION	Om	EGGS	288	720	2	5		0.0005	0.39	0.0005	0.21	0.22	0.38	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-90	LET	JUNCTION	Om	FAT	267.6	706.7	1	4		0.0005	0.4	0.0005	0.48	0.78	2.58	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-90	LET	JUNCTION	Om	FAT	398	650	1	2		0.0005	0.29	0.0005	1.51	0.94	1.18	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-90	LET	PRIESK_W	C	FAT	442	1030	1	2		0.0005	0.31	0.0005	3.09	3.41	1.68	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-90	LET	PRIESK_W	C	LIVER	430	910	1	1		0.0005	0.4	0.0005	0.54	0.46	0.39	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-90	LET	PRIESK_W	Bm	FAT	285	440	2	1		0.0005	0.36	0.0005	2.6	0.81	0.83	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-90	LET	PRIESK_W	C	FAT	472	910	1	4		0.0005	0.38	0.0005	2.81	1.7	1.27	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	JUNCTION	Om	FAT	262	680	2	5	4	0.08	0.88	0.0005	1.1	2.34	2.78	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	JUNCTION	C	FAT	628	2800	1	2	4	0.06	0.91	0.0005	2.33	2.23	2.95	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	PRIESK_W	C	LIVER	465	1200	2	2	2	0.0005	0.78	0.0005	0.76	0.8	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	PUMP_ST	Om	FAT	275	780	1	3	5	0.05	1.01	0.0005	2.2	3.14	4.88	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	PUMP_ST	Lr	GUT	235	320	1	2	2	0.07	0.79	0.0005	5.45	2.27	1.89	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	PUMP_ST	Bm	EGGS	272	520	2	5	1	0.0005	0.83	0.0005	0.97	0.83	0.79	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	PUMP_ST	C	FAT	498	1505	2	2	6	0.05	0.86	0.0005	2.14	2.16	2.37	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	PUMP_ST	Lr	LIVER	238.3	323.3	1	3	2	0.0005	0.78	0.0005	0.98	0.82	0.79	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	PUMP_ST	C	LIVER	462	1165	1	3	3	0.0005	0.77	0.0005	0.88	0.8	0.78	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-90	LET	SLAB_W	Om	EGGS	350	560	2	4	6	0.0005	0.8	0.0005	1.33	2.19	2.56	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-90	LET	ENGELHRD	Sd	EGGS	233	190	2	3		0.0005	0.18	0.0005	0.39	0.24	0.42	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-90	LET	ENGELHRD	Bm	EGGS	260	260	2	5		0.0005	0.18	0.0005	0.34	0.2	0.33	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-90	LET	ENGELHRD	Om	EGGS	210.3	226.3	2	3		0.0005	0.17	0.0005	0.26	0.22	0.19	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-90	LET	JUNCTION	Om	FAT	284.2	1225	1	4.5		0.23	0.35	0.04	0.78	1.15	2.11	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-90	LET	JUNCTION	Lm	EGGS	261	800	2	4		0.0005	0.17	0.0005	0.31	0.18	0.37	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-90	LET	PRIESK_W	Lm	EGGS	253	170	2	5		0.0005	0.17	0.0005	0.75	0.34	0.44	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-90	LET	SLAB_W	Om	EGGS	223	300	2	5	4	0.0005	0.17	0.0005	0.86	0.94	1.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-90	LET	SLAB_W	Lm	EGGS	215	250	2	5		0.0005	0.18	0.0005	0.87	0.35	0.53	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-91	LET	JUNCTION	Om	EGGS	262.5	760	2	4	4	0.0005	0.19	0.0005	0.26	0.43	0.56	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-91	LET	JUNCTION	Om	FAT	264.7	790	1.7	3.3	4	0.0005	0.3	0.0005	0.75	1.11	2.31	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-91	LET	PUMP_ST	Om	GUT	189	200	2	2	3	0.0005	0.19	0.0005	0.52	0.7	1.02	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-91	LET	SLAB_W	Om	GUT	183	300	2	6	1	0.0005	0.19	0.0005	0.29	0.46	0.48	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-91	LET	SLAB_W	Lm	GUT	192	180	2	3	1	0.0005	0.19	0.0005	0.9	0.62	0.92	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-91	LET	SLAB_W	Lm	EGGS	209	190	2	5	1	0.0005	0.19	0.0005	0.64	0.49	0.71	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-91	LET	JUNCTION	Om	LIVER	229.2	567.5	1.5	2	3.5	0.0005	0.01	0.0005	0.028	0.086	0.034	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-91	LET	JUNCTION	Om	FAT	229.2	567.5	1.5	2	3.5	0.0005	0.005	0.0005	0.222	1.904	2.304	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-91	LET	PRIESK_W	Om	EGGS	225.5	325	2	3	4	0.0005	0.005	0.0005	0.182	1.461	0.146	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-91	LET	PUMP_ST	Om	LIVER	246	818	1.2	2.8		0.0005	0.006	0.0005	0.039	0.106	0.027	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-91	LET	PUMP_ST	Om	FAT	267.5	995	1	3.5	6.5	0.0005	0.107	0.0005	0.776	5.338	4.787	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-91	LET	SLAB_W	C	EGGS	438	1200	2	4	3	0.0005	0.005	0.0005	0.235	0.764	0.983	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-91	LET	SLAB_W	Bm	EGGS	268	600	2	5	3	0.0005	0.016	0.0005	0.049	0.946	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	LET	ENGELHRD	C	FAT	764	6250	1	5		0 0005	0.094	0.0005	0.4	0.841	0.53	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	LET	PRIESK_F	C	FAT	615	3250	1	4		0.0005	0.005	0.0005	0.792	5.38	0.529	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	LET	PRIESK_F	Om	EGGS	210	373.3	2	3		0.0005	0.005	0.0005	0.303	1.053	0.379	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	LET	PRIESK_F	C	TESTES	615	3250	1	4		0.0005	0.005	0.0005	0.017	0.071	0.034	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	LET	PRIESK_F	C	FAT	517.5	1955	2	2.5		0.0005	0.002	0.0005	2.146	7.105	2.877	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	LET	PRIESK_F	Sd	EGGS	275	315.25	2	2.75		0.0005	0.3	0.0005	0.75	1.11	2.31	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	LET	PUMP_ST	Om	FAT	232 5	735	1	2.5		0.0005	0.128	0.0005	0.158	1.37	0.786	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	BHC	Dieldrin	Lindane	DDE	DDD	DDT	Heptachlor	Endosulfan	Mercapthion	Diazinon	Pirimiphos	Aldrin	Endrin	Atrazine
Aug-91	LET	SLAB_W	C	FAT	508	1825	1	4		0.0005	0.005	0.004	3.35	13.118	15.044	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	JUNCTION	Om	EGGS	251	590	2	6		0.0005	0.005	0.0005	0.052	0.243	0.51	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	JUNCTION	C	EGGS	436	930	2	5		0.0005	0.005	0.0005	0.046	0.041	0.083	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	JUNCTION	C	FAT	525	1700	1	5		0.0005	0.091	0.022	0.475	2.555	3.722	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	JUNCTION	C	EGGS	502	1590	2	5		0.0005	0.005	0.0005	0.037	0.155	0.075	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PRIESK_W	Om	EGGS	185.4	241.2	2	4.2		0.0005	0.005	0.0005	0.2	0.3	0.228	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PRIESK_W	C	EGGS	435	1000	2	4		0.0005	0.005	0.004	0.029	0.132	0 021	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PRIESK_W	C	EGGS	645	3550	2	5		0.0005	0.005	0.0005	0.36	0.059	0.188	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PRIESK_W	Sd	EGGS	245	204.7	2	3.7		0.0005	0.005	0.0005	0.18	0.384	0.175	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PRIESK_W	C	FAT	570	2175	1	4		0.0005	0.005	0.0005	3.014	18.076	5.026	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PUMP_ST	Om	LIVER	266	766	1	4		0.0005	0.026	0.0005	0.159	0.36	0.113	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PUMP_ST	Om	FAT	236	545	1	2		0.0005	0.005	0.0005	0.027	0.378	0.214	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PUMP_ST	Om	FAT	278	912	1	4		0.0005	0.072	0.013	0.534	3.845	2.428	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PUMP_ST	Om	EGGS	225.25	450.25	2	4.5		0.0005	0.005	0.0005	0.128	0.624	0.505	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PUMP_ST	Om	FAT	266	766	1	4		0.0005	0.005	0.012	0.007	0.002	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	PUMP_ST	Om	EGGS	226.25	444.75	2	4		0.0005	0.005	0.0005	0.246	1.072	1.053	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	SLAB_W	Lm	EGGS	251	477	2	5		0.0005	0.039	0.0005	0.272	0.92	0.814	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	SLAB_W	Lm	TESTES	237	444	1	5		0.0005	0.203	0.0005	0.445	1.046	0.791	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	SLAB_W	Lr	TESTES	312	960	1	5		0.0005	0.005	0.0005	3.244	6.352	2.759	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	SLAB_W	Om	EGGS	230	449.5	2	4.25		0.0005	0.005	0.0005	0.225	1.211	0.879	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Nov-91	LET	SLAB_W	C	FAT	420	1100	2	5		0.0005	0.005	0.0005	3.299	11.56	9.584	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	CAMP16	Sd	EGGS	276	329	2	3	4	0.0005	0.005	0.0005	0.22	0.14	0.11	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	JUNCTION	C	LIVER	638	2500	1	4	3	0.0005	0.02	0.0005	0.41	0.4	0.23	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	JUNCTION	Om	FAT	288.5	918	1	3.5	3.5	0.0005	0.08	0.0005	0.24	0.55	0.45	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	JUNCTION	C	FAT	638	2500	1	4	3	0.0005	0.02	0.0005	3 94	2.61	1.07	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	JUNCTION	Om	FAT	239	509	2	2	4	0.0005	0.09	0.0005	0.71	1.1	1.06	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	PRIESK_W	Sd	EGGS	226.3	170	2	2	2	0.0005	0.005	0.0005	0.12	0.11	0.12	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	PRIESK_W	C	EGGS	452	1100	2	3	2	0.0005	0.005	0.0005	0.03	0.04	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	PRIESK_W	C	LIVER	720	4000	1	5	2	0.0005	0.005	0.0005	0.13	0.21	0.03	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	PRIESK_W	Om	EGGS	219	416	2	3.333	3.333	0.0005	0.01	0.0005	0.59	0.8	0.22	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	LET	PRIESK_W	C	FAT	720	4000	1	5	2	0.0005	0.005	0.0005	2.9	3.95	2.79	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-93	LET	HUDSON	Lr	FAT	239	386.5	1.5	1.5		0.001	0.673	0.0005	3.85	1.999	0.262	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-93	LET	HUDSON	Om	FAT	281	842	2	4	2	0.001	0.05	0.0005	2.029	2.201	1.804	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-93	LET	HUDSON	Lr	FAT	227	314.5	1.5	1.5		0.001	0.027	0.0005	1.988	2.565	0.212	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-93	LET	HUDSON	Om	EGGS	281	842	2	4	2	0.001	0.014	0.0005	0.146	0.368	0.135	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-93	LET	MIDLET	C	LIVER	680	6250	1	2	5	0.001	0.005	0.0005	0.313	0.117	0.027	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-92	LEV	FARM	Unia	WHOLE						0.0005	0.005	0.0005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-92	LEV	MKYAUPST	Lr	LIVER	342	1260	2	2	2	0.0005	0.005	0.0005	0.07	0.036	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-92	LEV	MKYAUPST	Lc	FAT	324.5	1114 25	1.75	1.5	2	0.0005	0 005	0 0005	1.12	0.26	0.11	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-92	LEV	MKYAUPST	Lr	FAT	312.25	1014.5	1.75	1.25	2.3	0.0005	0.005	0.0005	0.37	0.14	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	OLI	LOSKOP	Lc	FAT						0.32	0.21	0.02	0.7	0.26	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	OLI	LOSKOP	Om	EGGS						0.0005	0.16	0.0005	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	OLI	LOSKOP	Sd	EGGS						0.0005	0.17	0.0005	0.19	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	OLI	LOSKOP	Lr	EGGS						0.0005	0 15	0.0005	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	OLI	LOSKOP	Lr	TESTES						0.0005	0.16	0.0005	0.15	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Oct-90	OLI	LOSKOP	C	EGGS						0.0005	0.16	0.0005	0.17	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	VYEBOOM	C	EGGS	840	4610	2			0.0005	0.005	0.0005	0.033	0 02	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	BALULI	Bm	EGGS						0.0005	0.004	0.002	0.004	0.005	0 005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	BHC	Dieldrin	Lindane	DDE	DDD	DDT	Heptachlor	Endosulfan	Mercapthion	Diazinon	Pirimiphos	Aldrin	Endrin	Atrazine
Aug-91	OLI	BALULI	C	FAT						0.0005	0.069	0.0005	0.017	0.206	0.097	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	BALULI	C	LIVER						0.0005	0.037	0.004	0.007	0.023	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	BALULI	Lr	LIVER						0.0005	0.044	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	BALULI	C	LIVER						0.0005	0.005	0.003	0.004	0.013	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	MAMBA_W	C	FAT						0.0005	0.051	0.0005	1.904	0.318	12.25	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	MAMBA_W	C	FAT						0.0005	0.004	0.002	0.464	2.091	2.583	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	MAMBA_W	C	EGGS						0.0005	0.004	0.002	0.011	0.011	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	MAMBA_W	C	EGGS						0.0005	0.005	0.003	0.008	0.021	0.008	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	MAMBA_W	C	LIVER						0.0005	0.01	0.003	0.122	0.18	0.09	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Aug-91	OLI	SELATI	Om	LIVER						0.0005	0.041	0.0005	0.087	0.073	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-92	OLI	MAMBA_W	Lc	EGGS	418	1027	2			0.0005	0.01	0.0005	0.02	0.014	0.008	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-92	OLI	MAMBA_W	Lr	FLESH	372	694	2			0.0005	0.005	0.0005	0.106	0.054	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-92	OLI	MAMBA_W	C	FAT	305	380	1			0.0005	0.04	0.0005	2.355	1.03	0.489	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-92	OLI	MAMBA_W	Lc	FLESH	418	1027	2			0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Feb-92	OLI	SELATI	C	EGGS	672	2500	2			0.0005	0.006	0.0005	0.051	0.035	0.008	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	MAMBA_W	C	LIVER	610	3400	2			0.0005	0.005	0.0005	0.021	0.018	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	MAMBA_W	C	LIVER	535	2007	2			0.0005	0.01	0.0005	0.009	0.096	0.007	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	MAMBA_W	C	LIVER	497	1310	2			0.0005	0.005	0.0005	0.015	0.016	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PRESELAT	C	FAT	880	8000	1	4	3	0.0005	0.005	0.0005	0.48	0.25	0.21	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PRESELAT	C	FAT	600	2800	2	1	3	0.0005	0.005	0.0005	0.96	0.55	0.47	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PRNEEF_D	C	LIVER	468	1544	2			0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PRNEEF_D	C	FLESH	468	1544	2			0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PRNEEF_D	C	EGGS	468	1544	2			0.0005	0.005	0.0005	0.194	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PSTSELAT	C	FAT	760	5500	2	2	6	0.0005	0.036	0.0005	3.99	4.27	1	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PSTSELAT	C	FAT	903	6200	1			0.0005	0.005	0.0005	0.283	0.1	0.06	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PSTSELAT	C	FAT	584	2400	1	3	2	0.0005	0.02	0.0005	0.76	0.76	0.2	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PSTSELAT	C	LIVER	760	5250	1	3	3	0.0005	0.005	0.0005	0.05	0.02	0.08	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-92	OLI	PSTSELAT	C	EGGS	760	5500	2	2	6	0.0005	0.005	0.0005	0.04	0.05	0.02	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-93	OLI	KLIPSPR	C	LIVER	527.5	1850	1	2	3.5	0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-93	OLI	KLIPSPR	C	TESTES	528.3	1833.3	1	2	3.3	0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-93	OLI	KLIPSPR	Bm	EGGS	267.5	400	2	5	4	0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-93	OLI	KLIPSPR	Bm	EGGS	265	500	2	5		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-93	OLI	KLIPSPR	C	EGGS	410	731	2	3		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jan-93	OLI	PSTSELAT	C	LIVER	475	1700	1	2		0.0005	0.005	0.0005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	OLI	BALULI	C	EGGS	420	725	2	4		0.001	0.564	0.0005	1.603	0.862	0.12	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	OLI	MEETWAL	Lc	GUT_FAT	330	937	2	2		0.001	0.013	0.0005	0.097	0.207	0.059	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	OLI	MEETWAL	Lc	GUT_FAT	325	857	1	2	3	0.001	0.02	0.0005	0.167	0.238	0.137	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	OLI	MEETWAL	C	FAT	570	2700	1	2	4	0.001	0.051	0.0005	1.501	1.678	0.867	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	OLI	MEETWAL	C	FAT	479	1300	1	4	6	0.001	0.06	0.0005	0.664	1.89	0.511	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-92	SAB	WEIR	Lrd	FAT	289	699	2	2	2	0.0005	0.005	0.0005	0.54	0.86	0.74	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-92	SAB	WEIR	Lc	FAT	325	1103	2	1.5	2	0.0005	0.005	0.0005	1.54	1.71	0.4	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-92	SAB	WEIR	Lr	FAT	316	1027	2	4	3	0.0005	0.03	0.0005	0.38	1	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-92	SAB	WEIR	Lr	EGGS	316	1027	2	4	3	0.0005	0.01	0.0005	0.15	0.17	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-92	SAB	WEIR	C	EGGS	435	1078	2	4	2	0.0005	0.005	0.0005	0.01	0.03	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-92	SAB	WEIR	Bm	FAT	299	816	2	3	3.5	0.0005	0.07	0.0005	0.68	1.7	0.07	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
May-92	SAB	WEIR	Sd	EGGS	285	362	2	3	3	0.0005	0.01	0.0005	0.05	0.05	0.03	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Lc	EGGS	306	897	2	2.3	1	0.001	0.008	0.0005	0.09	0.164	0.048	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Hv	FAT	331	705	2	2	2	0.001	0.031	0.0005	0.277	1.581	0.364	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005

Date	River	Site	spp	Tissue	Length	Mass	Gender	GI	Age	BHC	Dieldrin	Lindane	DDE	DDD	DDT	Heptachlor	Endosulfan	Mercapthion	Diazinon	Pirimiphos	Aldrin	Endrin	Atrazine
Jun-93	SAB	WEIR	Bm	EGGS	332	1000	2	3	4	0.001	0.005	0.0005	0.033	0.084	0.005	0.005	0.005	0.005	0.005	0 005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Bm	FAT	280	687	2	2	3	0.001	0.004	0.0005	0.039	1.074	0.007	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Bm	EGGS	366	1250	2	2	4	0.001	0.003	0.0005	0.037	0.1	0.007	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Bm	EGGS	384	1452	2	3	3	0.001	0.002	0.0005	0.183	0.388	0 009	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Lr	GUT&FAT	300	848	1	2		0.001	0.008	0.0005	0.068	0.25	0.033	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Bm	EGGS	392	1700	2	2	3	0.001	0.005	0.0005	0.012	0.16	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Bm	FAT	287	550	1	1		0.001	0.011	0.0005	0.184	0.54	0.023	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Lc	GUT&FAT	312	833	1	1	1	0.001	0.221	0.0005	0.966	0.931	0.234	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005
Jun-93	SAB	WEIR	Om	FAT	240	581	1	3	2	0.001	0.013	0.0005	0.123	0.731	0.158	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.0005

Appendix D1: The number, mean, standard deviation and range of the pesticides detected per tissue.

		Eggs(n=133)		Fat(n=106)		Testes(n=28)		Liver(n=53)		Flesh(n=37)		Gut(n=15)	
BHC	Mean±Sd	0.0039 ±	0.0238	0.0124 ±	0.0498	0.0137 ±	0.0489	0.0079 ±	0.0323	0.0006 ±	0.0007	0.0051 ±	0.0179
	Range	0.0005 -	0.2100	0.0005 -	0.3200	0.0005 -	0.2100	0.0005 -	0.2200	0.0005 -	0.0050	0.0005 -	0.0700
Lindane	Mean±Sd	0.0860 ±	0.1626	0.2644 ±	1.1383	0.1036 ±	0.1635	0.2032 ±	0.4270	0.0213 ±	0.0459	1.1679 ±	3.1711
	Range	0.0004 -	1.1800	0.0020 -	11.5900	0.0020 -	0.8300	0.0050 -	2.2200	0.0010 -	0.2700	0.0040 -	12.2700
Dieldrin	Mean±Sd	0.0008 ±	0.0018	0.0020 ±	0.0060	0.0019 ±	0.0051	0.0045 ±	0.0177	0.0040 ±	0.0196	0.0005 ±	0.0000
	Range	0.0005 -	0.0200	0.0005 -	0.0400	0.0005 -	0.0200	0.0005 -	0.0980	0.0005 -	0.1200	0.0005 -	0.0005
DDE	Mean±Sd	0.1821 ±	0.2756	0.9285 ±	1.0530	0.2314 ±	0.6028	0.2845 ±	0.6694	0.0147 ±	0.0249	0.5719 ±	1.3714
	Range	0.0010 -	1.6030	0.0020 -	3.9900	0.0010 -	3.2440	0.0040 -	4.6230	0.0008 -	0.1060	0.0050 -	5.4500
DDD	Mean±Sd	0.2389 ±	0.5716	1.4034 ±	2.6416	0.3034 ±	1.2017	0.2304 ±	0.4191	0.0310 ±	0.1395	0.3783 ±	0.6216
	Range	0.0050 -	5.3670	0.0020 -	18.0760	0.0050 -	6.3520	0.0050 -	1.9870	0.0050 -	0.8530	0.0050 -	2.2700
DDT	Mean±Sd	0.1899 ±	0.4763	1.0374 ±	2.2567	0.1756 ±	0.5372	0.0969 ±	0.2068	0.0050 ±	0.0000	0.5727 ±	0.9613
	Range	0.0050 -	3.4990	0.0020 -	15.0440	0.0050 -	2.7590	0.0050 -	0.8440	0.0050 -	0.0050	0.0050 -	3.4560
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0060 ±	0.0057	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0450	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0397 ±	0.2373	0.0931 ±	0.5932	0.0228 ±	0.0935	0.3691 ±	1.3471	0.0765 ±	0.2241	0.3729 ±	1.0099
	Range	0.0030 -	2.4850	0.0050 -	5.1100	0.0050 -	0.5000	0.0050 -	7.3540	0.0010 -	1.0730	0.0050 -	3.4990
Mercapthion	Mean±Sd	0.0056 ±	0.0074	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0060 ±	0.0076	0.0101 ±	0.0218	0.0050 ±	0.0000
	Range	0.0050 -	0.0900	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0600	0.0050 -	0.1000	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0058 ±	0.0052	0.0098 ±	0.0232	0.0096 ±	0.0218	0.0082 ±	0.0125	0.0193 ±	0.0193	0.0050 ±	0.0000
	Range	0.0050 -	0.0400	0.0050 -	0.2000	0.0050 -	0.1200	0.0050 -	0.0800	0.0050 -	0.0700	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0117 ±	0.0440	0.0050 ±	0.0000	0.0066 ±	0.0117	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.4300	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0433 ±	0.1485
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.5800
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0018 ±	0.0112	0.0092 ±	0.0801	0.0044 ±	0.0115	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.1100	0.0005 -	0.8200	0.0005 -	0.0400	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D2: The number, mean, standard deviation and range of the pesticides detected in each species tissues.

		O. mossambicus (n=71)		*C. carpio* (n=10)		*M. dolomieu* (n=1)		*L. molybdinus* (n=35)		*B. marequensis* (n=58)	
BHC	Mean±Sd	0.0060 ±	0.0294	0.0006 ±	0.0002	0.0005 ±	0.0000	0.0027 ±	0.0104	0.0084 ±	0.0361
	Range	0.0005 -	0.2300	0.0005 -	0.0010	0.0005 -	0.0005	0.0005 -	0.0600	0.0005 -	0.2100
Lindane	Mean±Sd	0.1305 ±	0.2324	0.0317 ±	0.0447	0.0050 ±	0.0000	0.8920 ±	2.7814	0.0876 ±	0.1706
	Range	0.0010 -	1.1300	0.0020 -	0.1500	0.0050 -	0.0050	0.0050 -	12.2700	0.0020 -	0.8500
Dieldrin	Mean±Sd	0.0045 ±	0.0187	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0010 ±	0.0027
	Range	0.0005 -	0.1200	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0200
DDE	Mean±Sd	0.3211 ±	0.4560	0.0371 ±	0.0358	0.0200 ±	0.0000	0.2242 ±	0.2786	0.3544 ±	0.7840
	Range	0.0008 -	2.2000	0.0050 -	0.1100	0.0200 -	0.0200	0.0020 -	0.9000	0.0040 -	4.6230
DDD	Mean±Sd	0.6058 ±	0.9587	0.0288 ±	0.0484	0.1500 ±	0.0000	0.2139 ±	0.4478	0.2950 ±	0.7898
	Range	0.0020 -	5.3380	0.0050 -	0.1600	0.1500 -	0.1500	0.0050 -	2.3000	0.0050 -	5.3670
DDT	Mean±Sd	0.5839 ±	1.0491	0.0096 ±	0.0135	0.0050 ±	0.0000	0.1893 ±	0.2893	0.1455 ±	0.4960
	Range	0.0050 -	4.8800	0.0050 -	0.0480	0.0050 -	0.0050	0.0050 -	0.9200	0.0050 -	3.4990
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0053 ±	0.0019	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0160	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0160 ±	0.0763	0.0050 ±	0.0000	0.0050 ±	0.0000	0.6568 ±	1.6586	0.1725 ±	0.8245
	Range	0.0010 -	0.6300	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	7.3540	0.0050 -	5.1100
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0090 ±	0.0169	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0070 ±	0.0111	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0100 ±	0.0150	0.0092 ±	0.0132
	Range	0.0050 -	0.0800	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0800	0.0050 -	0.0700
Pirimiphos	Mean±Sd	0.0066 ±	0.0136	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0074 ±	0.0144	0.0050 ±	0.0000
	Range	0.0050 -	0.1200	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0131 ±	0.0682	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.5800	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0150 ±	0.0985	0.0183 ±	0.0251	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.8200	0.0005 -	0.0700	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D2: cont.

		H. vittatus (n=7)		*C. gariepinus* (n=124)		*L. rosae* (n=24)		*T. rendalli* (n=19)		*S. zambezensis* (n=1)	
BHC	Mean±Sd	0.0074 ±	0.0179	0.0070 ±	0.0357	0.0035 ±	0.0142	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0480	0.0005 -	0.2500	0.0005 -	0.0700	0.0005 -	0.0005	0.0005 -	0.0005
Lindane	Mean±Sd	0.8016 ±	1.3038	0.1061 ±	0.2066	0.1197 ±	0.2467	0.0872 ±	0.1391	0.0100 ±	0.0000
	Range	0.0050 -	3.1200	0.0004 -	0.9600	0.0040 -	0.7900	0.0050 -	0.4100	0.0100 -	0.0100
Dieldrin	Mean±Sd	0.0126 ±	0.0319	0.0017 ±	0.0045	0.0007 ±	0.0011	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0850	0.0005 -	0.0300	0.0005 -	0.0060	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.4406 ±	0.5645	0.5637 ±	0.9634	0.8261 ±	1.4091	0.0951 ±	0.1462	0.0400 ±	0.0000
	Range	0.0050 -	1.3700	0.0010 -	3.9900	0.0050 -	5.4500	0.0020 -	0.5300	0.0400 -	0.0400
DDD	Mean±Sd	0.8016 ±	0.6209	0.8965 ±	2.4712	0.6882 ±	1.4243	0.0771 ±	0.1192	0.0200 ±	0.0000
	Range	0.0050 -	1.5810	0.0050 -	18.0760	0.0050 -	6.3520	0.0050 -	0.4000	0.0200 -	0.0200
DDT	Mean±Sd	0.9184 ±	1.2140	0.6306 ±	2.0437	0.2633 ±	0.6692	0.0836 ±	0.1487	0.0200 ±	0.0000
	Range	0.0050 -	3.4560	0.0050 -	15.0440	0.0050 -	2.7590	0.0020 -	0.6000	0.0200 -	0.0200
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0067 ±	0.0082	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0450	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0613 ±	0.3474	0.0401 ±	0.1161	0.0475 ±	0.1846	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0030 -	3.3300	0.0050 -	0.5130	0.0050 -	0.8100	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0058 ±	0.0086	0.0050 ±	0.0000	0.0100 ±	0.0218	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.1000	0.0050 -	0.0050	0.0050 -	0.1000	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0085 ±	0.0123	0.0050 ±	0.0000	0.0284 ±	0.0512	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050	0.0050 -	0.2000	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0064 ±	0.0108	0.0050 ±	0.0000	0.0274 ±	0.0975	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050	0.0050 -	0.4300	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D2 : cont.

		L. congoro (n=18)		*B. imberi* (n=1)		*S. intermedius* (n=8)		*L. ruddi* (n=1)	
BHC	Mean±Sd	0.0389 ±	0.0923	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.3200	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
Lindane	Mean±Sd	0.0921 ±	0.0899	0.1700 ±	0.0000	0.1044 ±	0.1133	0.0050 ±	0.0000
	Range	0.0050 -	0.2400	0.1700 -	0.1700	0.0050 -	0.3000	0.0050 -	0.0050
Dieldrin	Mean±Sd	0.0027 ±	0.0063	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0200	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.3747 ±	0.4336	0.1700 ±	0.0000	0.2600 ±	0.2204	0.5400 ±	0.0000
	Range	0.0050 -	1.5400	0.1700 -	0.1700	0.0500 -	0.7500	0.5400 -	0.5400
DDD	Mean±Sd	0.2577 ±	0.4208	0.2000 ±	0.0000	0.2761 ±	0.3566	0.8600 ±	0.0000
	Range	0.0050 -	1.7100	0.2000 -	0.2000	0.0050 -	1.1100	0.8600 -	0.8600
DDT	Mean±Sd	0.1009 ±	0.1088	0.1600 ±	0.0000	0.4163 ±	0.7755	0.7400 ±	0.0000
	Range	0.0050 -	0.4000	0.1600 -	0.1600	0.0050 -	2.3100	0.7400 -	0.7400
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0064 ±	0.0059	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0300	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D3: The number, mean, standard deviation and range of the pesticides analyzed for different tissues per species.

O. mossambicus		Eggs (n=24)		Fat (n=31)		Testes (n=1)		Liver (n=7)		Flesh (n=4)		Gut (n=4)	
BHC	Mean±Sd	0.0005 ±	0.0001	0.0121 ±	0.0437	0.0005 ±	0.0000	0.0051 ±	0.0123	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0010	0.0005 -	0.2300	0.0005 -	0.0005	0.0005 -	0.0330	0.0005 -	0.0005	0.0005 -	0.0005
Dieldrin	Mean±Sd	0.1118 ±	0.1881	0.1783 ±	0.2961	0.0100 ±	0.0000	0.0234 ±	0.0250	0.0153 ±	0.0232	0.2050 ±	0.1642
	Range	0.0050 -	0.8000	0.0050 -	1.1300	0.0100 -	0.0100	0.0050 -	0.0710	0.0010 -	0.0500	0.0200 -	0.4200
Lindane	Mean±Sd	0.0006 ±	0.0003	0.0025 ±	0.0076	0.0005 ±	0.0000	0.0144 ±	0.0369	0.0304 ±	0.0598	0.0005 ±	0.0000
	Range	0.0005 -	0.0020	0.0005 -	0.0400	0.0005 -	0.0005	0.0005 -	0.0980	0.0005 -	0.1200	0.0005 -	0.0005
DDE	Mean±Sd	0.2306 ±	0.3053	0.5081 ±	0.5775	0.0030 ±	0.0000	0.0680 ±	0.0661	0.0030 ±	0.0024	0.2550 ±	0.2063
	Range	0.0010 -	1.3300	0.0070 -	2.2000	0.0030 -	0.0030	0.0050 -	0.1590	0.0008 -	0.0050	0.0300 -	0.5200
DDD	Mean±Sd	0.4796 ±	0.5768	0.9427 ±	1.2732	0.0050 ±	0.0000	0.1524 ±	0.1720	0.0050 ±	0.0000	0.2963 ±	0.3420
	Range	0.0050 -	2.1900	0.0020 -	5.3380	0.0050 -	0.0050	0.0050 -	0.4320	0.0050 -	0.0050	0.0050 -	0.7000
DDT	Mean±Sd	0.3857 ±	0.5728	0.9788 ±	1.4039	0.0050 ±	0.0000	0.0407 ±	0.0454	0.0050 ±	0.0000	0.3863 ±	0.4746
	Range	0.0050 -	2.5600	0.0050 -	4.8800	0.0050 -	0.0050	0.0050 -	0.1130	0.0050 -	0.0050	0.0050 -	1.0200
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0279 ±	0.0605	0.1603 ±	0.3132	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.1650	0.0010 -	0.6300	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0074 ±	0.0135	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0225 ±	0.0260	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0800	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0600	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0087 ±	0.0207	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.1200	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.1488 ±	0.2875
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.5800
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0051 ±	0.0224	0.0301 ±	0.1477	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.1100	0.0005 -	0.8200	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D3: cont.

		C. carpio						*M. dolomieu*	
		Eggs(n=4)		Fat(n=2)		Testes(n=3)		Eggs(n=1)	
BHC	Mean±Sd	0.0006 ±	0.0003	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0010	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
Dieldrin	Mean±Sd	0.0153 ±	0.0167	0.0390 ±	0.0156	0.0577 ±	0.0805	0.0050 ±	0.0000
	Range	0.0050 -	0.0400	0.0280 -	0.0500	0.0020 -	0.1500	0.0050 -	0.0050
Lindane	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.0288 ±	0.0202	0.0990 ±	0.0156	0.0127 ±	0.0042	0.0200 ±	0.0000
	Range	0.0050 -	0.0500	0.0880 -	0.1100	0.0080 -	0.0160	0.0200 -	0.0200
DDD	Mean±Sd	0.0163 ±	0.0225	0.0935 ±	0.0940	0.0103 ±	0.0068	0.1500 ±	0.0000
	Range	0.0050 -	0.0500	0.0270 -	0.1600	0.0050 -	0.0180	0.1500 -	0.1500
DDT	Mean±Sd	0.0050 ±	0.0000	0.0065 ±	0.0021	0.0193 ±	0.0248	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0080	0.0050 -	0.0480	0.0050 -	0.0050
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0179 ±	0.0348	0.0005 ±	0.0000	0.0367 ±	0.0058	0.0005 ±	0.0000
	Range	0.0005 -	0.0700	0.0005 -	0.0005	0.0300 -	0.0400	0.0005 -	0.0005

Appendix D3: cont.

L. molybdinus		Eggs (n=14)		Fat (n=1)		Testes (n=5)		Liver (n=4)		Flesh (n=7)		Gut (n=4)	
BHC	Mean±Sd	0.0048 ±	0.0159	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0049 ±	0.0088	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0600	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0180	0.0005 -	0.0005	0.0005 -	0.0005
Dieldrin	Mean±Sd	0.1899 ±	0.2980	11.5900 ±	0.0000	0.1418 ±	0.0780	0.8088 ±	0.6930	0.0484 ±	0.0985	3.1725 ±	6.0656
	Range	0.0050 -	1.1800	11.5900 -	11.5900	0.0060 -	0.2030	0.0780 -	1.5170	0.0050 -	0.2700	0.0200 -	12.2700
Lindane	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.2635 ±	0.2987	0.0050 ±	0.0000	0.2092 ±	0.1543	0.3578 ±	0.3373	0.0071 ±	0.0057	0.4063 ±	0.3820
	Range	0.0020 -	0.8700	0.0050 -	0.0050	0.0210 -	0.4450	0.0050 -	0.7600	0.0050 -	0.0200	0.0050 -	0.9000
DDD	Mean±Sd	0.1771 ±	0.2694	2.3000 ±	0.0000	0.2780 ±	0.4349	0.1120 ±	0.2140	0.0050 ±	0.0000	0.2088 ±	0.2832
	Range	0.0050 -	0.9200	2.3000 -	2.3000	0.0050 -	1.0460	0.0050 -	0.4330	0.0050 -	0.0050	0.0050 -	0.6200
DDT	Mean±Sd	0.2356 ±	0.2884	0.5300 ±	0.0000	0.2712 ±	0.3743	0.0050 ±	0.0000	0.0050 ±	0.0000	0.3463 ±	0.4292
	Range	0.0050 -	0.8140	0.5300 -	0.5300	0.0050 -	0.7910	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.9200
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0078 ±	0.0055	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0160	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.2009 ±	0.6611	0.0050 ±	0.0000	0.1040 ±	0.2214	3.3723 ±	3.6484	0.0891 ±	0.2226	1.3848 ±	1.7023
	Range	0.0050 -	2.4850	0.0050 -	0.0050	0.0050 -	0.5000	0.0050 -	7.3540	0.0050 -	0.5940	0.0050 -	3.4990
Mercapthion	Mean±Sd	0.0111 ±	0.0227	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0188 ±	0.0275	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0900	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0600	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0075 ±	0.0094	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0238 ±	0.0375	0.0143 ±	0.0134	0.0050 ±	0.0000
	Range	0.0050 -	0.0400	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0800	0.0050 -	0.0400	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0263 ±	0.0425	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D3: cont.

B. marequensis		Eggs (n=23)	Fat (n=13)	Testes (n=4)	Liver (n=6)	Flesh (n=8)	Gut (n=4)
BHC	Mean ± Sd	0.0080 ± 0.0353	0.0006 ± 0.0002	0.0529 ± 0.1048	0.0128 ± 0.0300	0.0011 ± 0.0016	0.0005 ± 0.0000
	Range	0.0005 - 0.1700	0.0005 - 0.0010	0.0005 - 0.2100	0.0005 - 0.0740	0.0005 - 0.0050	0.0005 - 0.0005
Dieldrin	Mean ± Sd	0.0878 ± 0.1764	0.1778 ± 0.2528	0.0550 ± 0.0708	0.0450 ± 0.0556	0.0153 ± 0.0176	0.0338 ± 0.0197
	Range	0.0020 - 0.8300	0.0040 - 0.8500	0.0050 - 0.1600	0.0050 - 0.1510	0.0050 - 0.0470	0.0050 - 0.0500
Lindane	Mean ± Sd	0.0006 ± 0.0003	0.0005 ± 0.0000	0.0054 ± 0.0098	0.0005 ± 0.0000	0.0014 ± 0.0027	0.0005 ± 0.0000
	Range	0.0005 - 0.0020	0.0005 - 0.0005	0.0005 - 0.0200	0.0005 - 0.0005	0.0005 - 0.0080	0.0005 - 0.0005
DDE	Mean ± Sd	0.1856 ± 0.2675	0.7610 ± 0.9377	0.0803 ± 0.0822	0.8422 ± 1.8536	0.0208 ± 0.0235	0.2138 ± 0.2639
	Range	0.0040 - 0.9700	0.0050 - 2.6000	0.0070 - 0.1700	0.0050 - 4.6230	0.0050 - 0.0710	0.0050 - 0.6000
DDD	Mean ± Sd	0.3838 ± 1.1152	0.4417 ± 0.5253	0.0525 ± 0.0723	0.3353 ± 0.8091	0.0131 ± 0.0230	0.0538 ± 0.0594
	Range	0.0050 - 5.3670	0.0050 - 1.7000	0.0100 - 0.1600	0.0050 - 1.9870	0.0050 - 0.0700	0.0050 - 0.1400
DDT	Mean ± Sd	0.2158 ± 0.7365	0.1719 ± 0.3050	0.0438 ± 0.0775	0.1448 ± 0.3425	0.0050 ± 0.0000	0.0388 ± 0.0266
	Range	0.0050 - 3.4990	0.0050 - 0.8300	0.0050 - 0.1600	0.0050 - 0.8440	0.0050 - 0.0050	0.0050 - 0.0700
Heptachlor	Mean ± Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endosulfan	Mean ± Sd	0.0275 ± 0.0803	0.3977 ± 1.4159	0.0050 ± 0.0000	0.6297 ± 1.5301	0.0479 ± 0.1213	0.0050 ± 0.0000
	Range	0.0050 - 0.3870	0.0050 - 5.1100	0.0050 - 0.0050	0.0050 - 3.7530	0.0050 - 0.3480	0.0050 - 0.0050
Mercapthion	Mean ± Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Diazinon	Mean ± Sd	0.0065 ± 0.0073	0.0092 ± 0.0153	0.0050 ± 0.0000	0.0108 ± 0.0143	0.0200 ± 0.0230	0.0050 ± 0.0000
	Range	0.0050 - 0.0400	0.0050 - 0.0600	0.0050 - 0.0050	0.0050 - 0.0400	0.0050 - 0.0700	0.0050 - 0.0050
Pirimiphos	Mean ± Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Aldrin	Mean ± Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endrin	Mean ± Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Atrazine	Mean ± Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005

Appendix D3: cont.

H. vittatus		Eggs (n=2)		Fat (n=2)		Liver (n=1)		Flesh (n=1)		Gut (n=1)	
BHC	Mean±Sd	0.0005 ±	0.0000	0.0008 ±	0.0004	0.0480 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0010	0.0480 -	0.0480	0.0005 -	0.0005	0.0005 -	0.0005
Dieldrin	Mean±Sd	0.0875 ±	0.1167	0.0455 ±	0.0205	2.2200 ±	0.0000	0.0050 ±	0.0000	3.1200 ±	0.0000
	Range	0.0050 -	0.1700	0.0310 -	0.0600	2.2200 -	2.2200	0.0050 -	0.0050	3.1200 -	3.1200
Lindane	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0850 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0850 -	0.0850	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.7750 ±	0.8415	0.7035 ±	0.6032	0.0540 ±	0.0000	0.0050 ±	0.0000	0.0680 ±	0.0000
	Range	0.1800 -	1.3700	0.2770 -	1.1300	0.0540 -	0.0540	0.0050 -	0.0050	0.0680 -	0.0680
DDD	Mean±Sd	0.6425 ±	0.9016	1.0805 ±	0.7078	1.0400 ±	0.0000	0.0050 ±	0.0000	1.1200 ±	0.0000
	Range	0.0050 -	1.2800	0.5800 -	1.5810	1.0400 -	1.0400	0.0050 -	0.0050	1.1200 -	1.1200
DDT	Mean±Sd	0.7950 ±	0.8556	0.5770 ±	0.3012	0.2240 ±	0.0000	0.0050 ±	0.0000	3.4560 ±	0.0000
	Range	0.1900 -	1.4000	0.3640 -	0.7900	0.2240 -	0.2240	0.0050 -	0.0050	3.4560 -	3.4560
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D3: cont.

C. gariepinus		Eggs (n=36)		Fat (n=40)		Testes (n=7)		Liver (n=29)		Flesh (n=11)	
BHC	Mean±Sd	0.0006 ±	0.0006	0.0150 ±	0.0516	0.0006 ±	0.0002	0.0081 ±	0.0408	0.0005 ±	0.0000
	Range	0.0005 -	0.0040	0.0005 -	0.2500	0.0005 -	0.0010	0.0005 -	0.2200	0.0005 -	0.0005
Dieldrin	Mean±Sd	0.0455 ±	0.1016	0.1617 ±	0.2525	0.1656 ±	0.3014	0.1232 ±	0.2264	0.0195 ±	0.0259
	Range	0.0004 -	0.5640	0.0020 -	0.9600	0.0040 -	0.8300	0.0050 -	0.7800	0.0050 -	0.0770
Lindane	Mean±Sd	0.0013 ±	0.0033	0.0025 ±	0.0064	0.0005 ±	0.0000	0.0015 ±	0.0037	0.0008 ±	0.0011
	Range	0.0005 -	0.0200	0.0005 -	0.0300	0.0005 -	0.0005	0.0005 -	0.0200	0.0005 -	0.0040
DDE	Mean±Sd	0.1120 ±	0.2681	1.4814 ±	1.2256	0.0511 ±	0.0713	0.1911 ±	0.2590	0.0140 ±	0.0282
	Range	0.0050 -	1.6030	0.0170 -	3.9900	0.0010 -	0.1600	0.0040 -	0.8800	0.0050 -	0.0990
DDD	Mean±Sd	0.1007 ±	0.2147	2.4793 ±	3.8885	0.0144 ±	0.0249	0.2229 ±	0.3864	0.0821 ±	0.2557
	Range	0.0050 -	0.8620	0.0050 -	18.0760	0.0050 -	0.0710	0.0050 -	1.8150	0.0050 -	0.8530
DDT	Mean±Sd	0.0550 ±	0.1663	1.8134 ±	3.2993	0.0091 ±	0.0110	0.1008 ±	0.1904	0.0050 ±	0.0000
	Range	0.0050 -	0.9830	0.0050 -	15.0440	0.0050 -	0.0340	0.0050 -	0.7800	0.0050 -	0.0050
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0348 ±	0.1780	0.0906 ±	0.5255	0.0056 ±	0.0015	0.0518 ±	0.2470	0.1021 ±	0.3220
	Range	0.0030 -	1.0730	0.0050 -	3.3300	0.0050 -	0.0090	0.0050 -	1.3360	0.0050 -	1.0730
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0136 ±	0.0286
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.1000
Diazinon	Mean±Sd	0.0060 ±	0.0058	0.0085 ±	0.0158	0.0071 ±	0.0057	0.0071 ±	0.0079	0.0218 ±	0.0181
	Range	0.0050 -	0.0400	0.0050 -	0.0900	0.0050 -	0.0200	0.0050 -	0.0400	0.0050 -	0.0500
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0093 ±	0.0188	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D3: cont.

L. rosae		Eggs (n=5)		Fat (n=4)		Testes (n=4)		Liver (n=5)		Flesh (n=2)		Gut (n=4)	
BHC	Mean±Sd	0.0005 ±	0.0000	0.0008 ±	0.0003	0.0006 ±	0.0003	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0180 ±	0.0347
	Range	0.0005 -	0.0005	0.0005 -	0.0010	0.0005 -	0.0010	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0700
Dieldrin	Mean±Sd	0.0424 ±	0.0621	0.1838 ±	0.3264	0.0488 ±	0.0744	0.1816 ±	0.3349	0.0050 ±	0.0000	0.2030 ±	0.3913
	Range	0.0050 -	0.1500	0.0050 -	0.6730	0.0050 -	0.1600	0.0050 -	0.7800	0.0050 -	0.0050	0.0040 -	0.7900
Lindane	Mean±Sd	0.0016 ±	0.0025	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0060	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.2052 ±	0.1178	1.6470 ±	1.6538	0.9760 ±	1.5144	0.5038 ±	0.5082	0.0555 ±	0.0714	1.4195 ±	2.6870
	Range	0.0800 -	0.3860	0.3700 -	3.8500	0.1500 -	3.2440	0.0050 -	1.0960	0.0050 -	0.1060	0.0680 -	5.4500
DDD	Mean±Sd	0.0740 ±	0.0801	1.4260 ±	1.0741	1.6243 ±	3.1521	0.2352 ±	0.3512	0.0295 ±	0.0346	0.6775 ±	1.0659
	Range	0.0050 -	0.1700	0.1400 -	2.5650	0.0050 -	6.3520	0.0050 -	0.8200	0.0050 -	0.0540	0.0200 -	2.2700
DDT	Mean±Sd	0.0174 ±	0.0250	0.1210 ±	0.1355	0.6935 ±	1.3770	0.1620 ±	0.3511	0.0050 ±	0.0000	0.5383 ±	0.9036
	Range	0.0050 -	0.0620	0.0050 -	0.2620	0.0050 -	2.7590	0.0050 -	0.7900	0.0050 -	0.0050	0.0330 -	1.8900
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0130 ±	0.0179	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0450	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0610 ±	0.1252	0.0050 ±	0.0000	0.0050 ±	0.0000	0.1176 ±	0.2223	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.2850	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.5130	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D3: cont.

		T. rendalli										S. zambezensis	
		Eggs(n=6)		Fat(n=9)		Testes(n=1)		Liver(n=1)		Flesh(n=2)		Eggs(n=1)	
BHC	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
Dieldrin	Mean±Sd	0.0390 ±	0.0606	0.1119 ±	0.1550	0.0050 ±	0.0000	0.4000 ±	0.0000	0.0050 ±	0.0000	0.0100 ±	0.0000
	Range	0.0050 -	0.1600	0.0050 -	0.4100	0.0050 -	0.0050	0.4000 -	0.4000	0.0050 -	0.0050	0.0100 -	0.0100
Lindane	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.0535 ±	0.0569	0.1578 ±	0.1925	0.0500 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0400 ±	0.0000
	Range	0.0020 -	0.1600	0.0020 -	0.5300	0.0500 -	0.0500	0.0050 -	0.0050	0.0050 -	0.0050	0.0400 -	0.0400
DDD	Mean±Sd	0.0437 ±	0.0584	0.1313 ±	0.1520	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0200 ±	0.0000
	Range	0.0050 -	0.1600	0.0050 -	0.4000	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0200 -	0.0200
DDT	Mean±Sd	0.0370 ±	0.0522	0.1401 ±	0.2012	0.0900 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0200 ±	0.0000
	Range	0.0050 -	0.1400	0.0020 -	0.6000	0.0900 -	0.0900	0.0050 -	0.0050	0.0050 -	0.0050	0.0200 -	0.0200
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0053 ±	0.0008	0.0946 ±	0.2683	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0070	0.0050 -	0.8100	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0525 ±	0.0672	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.1000	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0317 ±	0.0649	0.1200 ±	0.0000	0.0050 ±	0.0000	0.0500 ±	0.0141	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.2000	0.1200 -	0.1200	0.0050 -	0.0050	0.0400 -	0.0600	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0522 ±	0.1417	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.4300	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D3: cont.

L. congoro		Eggs (n=7)		Fat (n=3)		Testes (n=3)		Flesh (n=2)		Gut (n=3)	
BHC	Mean±Sd	0.0306 ±	0.0791	0.1070 ±	0.1845	0.0537 ±	0.0921	0.0005 ±	0.0000	0.0010 ±	0.0000
	Range	0.0005 -	0.2100	0.0005 -	0.3200	0.0005 -	0.1600	0.0005 -	0.0005	0.0010 -	0.0010
Dieldrin	Mean±Sd	0.1040 ±	0.0776	0.0733 ±	0.1184	0.1433 ±	0.1060	0.0125 ±	0.0106	0.0847 ±	0.1181
	Range	0.0080 -	0.1800	0.0050 -	0.2100	0.0300 -	0.2400	0.0050 -	0.0200	0.0130 -	0.2210
Lindane	Mean±Sd	0.0005 ±	0.0000	0.0070 ±	0.0113	0.0070 ±	0.0113	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0200	0.0005 -	0.0200	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.1943 ±	0.1654	1.1200 ±	0.4200	0.2533 ±	0.0874	0.0175 ±	0.0177	0.4100 ±	0.4828
	Range	0.0200 -	0.5400	0.7000 -	1.5400	0.1800 -	0.3500	0.0050 -	0.0300	0.0970 -	0.9660
DDD	Mean±Sd	0.1097 ±	0.1016	0.7433 ±	0.8372	0.0850 ±	0.0776	0.0050 ±	0.0000	0.4587 ±	0.4093
	Range	0.0050 -	0.2600	0.2600 -	1.7100	0.0050 -	0.1600	0.0050 -	0.0050	0.2070 -	0.9310
DDT	Mean±Sd	0.0444 ±	0.0566	0.2233 ±	0.1550	0.1317 ±	0.1107	0.0050 ±	0.0000	0.1433 ±	0.0877
	Range	0.0050 -	0.1500	0.1100 -	0.4000	0.0050 -	0.2100	0.0050 -	0.0050	0.0590 -	0.2340
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0175 ±	0.0177	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0300	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D3: cont.

		B. imberi	*S. intermedius*	*H. molitrix*	*L. ruddi*
		Eggs(n=1)	Eggs(n=8)	Eggs(n=1)	Fat(n=1)
BHC	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005
Dieldrin	Mean±Sd	0.1700 ± 0.0000	0.1044 ± 0.1133	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.1700 - 0.1700	0.0050 - 0.3000	0.0050 - 0.0050	0.0050 - 0.0050
Lindane	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005
DDE	Mean±Sd	0.1700 ± 0.0000	0.2600 ± 0.2204	0.0200 ± 0.0000	0.5400 ± 0.0000
	Range	0.1700 - 0.1700	0.0500 - 0.7500	0.0200 - 0.0200	0.5400 - 0.5400
DDD	Mean±Sd	0.2000 ± 0.0000	0.2761 ± 0.3566	0.0050 ± 0.0000	0.8600 ± 0.0000
	Range	0.2000 - 0.2000	0.0050 - 1.1100	0.0050 - 0.0050	0.8600 - 0.8600
DDT	Mean±Sd	0.1600 ± 0.0000	0.4163 ± 0.7755	0.0050 ± 0.0000	0.7400 ± 0.0000
	Range	0.1600 - 0.1600	0.0050 - 2.3100	0.0050 - 0.0050	0.7400 - 0.7400
Heptachlor	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endosulfan	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Mercapthion	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Diazinon	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Pirimiphos	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Aldrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Atrazine	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005

Appendix D4: The number, mean, standard deviation and range of the pesticides detected in each river sampled.

		Crocodile (n=187)		Letaba (n=81)		Luvuvhu (n=8)		Olifants (n=65)		Sabie (n=18)	
BHC	Mean±Sd	0.0094 ±	0.0398	0.0072 ±	0.0293	0.0006 ±	0.0002	0.0057 ±	0.0396	0.0008 ±	0.0003
	Range	0.0005 -	0.2500	0.0005 -	0.2300	0.0005 -	0.0010	0.0005 -	0.3200	0.0005 -	0.0010
Dieldrin	Mean±Sd	0.2662 ±	1.2632	0.1973 ±	0.2775	0.0150 ±	0.0187	0.0735 ±	0.1852	0.0248 ±	0.0516
	Range	0.0004 -	12.2700	0.0020 -	1.0100	0.0050 -	0.0500	0.0040 -	1.1300	0.0020 -	0.2210
Lindane	Mean±Sd	0.0029 ±	0.0133	0.0016 ±	0.0053	0.0005 ±	0.0000	0.0011 ±	0.0026	0.0005 ±	0.0000
	Range	0.0005 -	0.1200	0.0005 -	0.0400	0.0005 -	0.0005	0.0005 -	0.0200	0.0005 -	0.0005
DDE	Mean±Sd	0.2348 ±	0.5504	0.9548 ±	1.1569	0.5163 ±	0.4846	0.3612 ±	0.6781	0.2979 ±	0.4063
	Range	0.0008 -	4.6230	0.0070 -	5.4500	0.0100 -	1.3700	0.0010 -	3.9900	0.0100 -	1.5400
DDD	Mean±Sd	0.1632 ±	0.5045	1.7340 ±	2.9079	1.0089 ±	1.9936	0.2834 ±	0.6643	0.6402 ±	0.5860
	Range	0.0050 -	5.3670	0.0020 -	18.0760	0.0050 -	5.8400	0.0050 -	4.2700	0.0300 -	1.7100
DDT	Mean±Sd	0.1201 ±	0.3943	1.3350 ±	2.1638	0.2379 ±	0.4736	0.3043 ±	1.5480	0.1199 ±	0.1987
	Range	0.0020 -	3.4990	0.0050 -	15.0440	0.0050 -	1.4000	0.0050 -	12.2500	0.0050 -	0.7400
Heptachlor	Mean±Sd	0.0053 ±	0.0030	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0450	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.2291 ±	0.9156	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0010 -	7.3540	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0068 ±	0.0122	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.1000	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0127 ±	0.0226	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.2000	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0093 ±	0.0338	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.4300	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0081 ±	0.0420	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.5800	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D5: The number, mean, standard deviation and range of the pesticides analyzed for each site per river.

Berg		Misverstand (n=1)		Voëlvlei (n=8)	
BHC	Mean±Sd	0.0005 ±	0.0000	0.0006 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005
Lindane	Mean±Sd	0.0345 ±	0.0349	0.0340 ±	0.0349
	Range	0.0050 -	0.1000	0.0020 -	0.1000
Dieldrin	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.0640 ±	0.0494	0.0389 ±	0.0494
	Range	0.0130 -	0.1800	0.0050 -	0.1800
DDD	Mean±Sd	0.0432 ±	0.0414	0.0473 ±	0.0414
	Range	0.0050 -	0.1300	0.0050 -	0.1300
DDT	Mean±Sd	0.0065 ±	0.0042	0.0108 ±	0.0042
	Range	0.0050 -	0.0190	0.0050 -	0.0190
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.2595 ±	0.2749	0.0316 ±	0.2749
	Range	0.0070 -	0.8200	0.0005 -	0.8200

Appendix D5: cont.

Crocodile		Hengel (n=34)	Mataffin (n=24)	Riverside (n=34)	Tenbosch (n=53)
BHC	Mean±Sd	0.0067 ± 0.0359	0.0014 ± 0.0036	0.0265 ± 0.0622	0.0020 ± 0.0078
	Range	0.0005 - 0.2100	0.0005 - 0.0180	0.0005 - 0.2100	0.0005 - 0.0480
Lindane	Mean±Sd	0.1462 ± 0.2975	0.1167 ± 0.2163	0.8559 ± 2.8262	0.1786 ± 0.5194
	Range	0.0050 - 1.5170	0.0040 - 0.9600	0.0004 - 12.2700	0.0010 - 3.1200
Dieldrin	Mean±Sd	0.0011 ± 0.0033	0.0008 ± 0.0010	0.0019 ± 0.0048	0.0063 ± 0.0237
	Range	0.0005 - 0.0200	0.0005 - 0.0040	0.0005 - 0.0200	0.0005 - 0.1200
DDE	Mean±Sd	0.2431 ± 0.3623	0.3711 ± 0.7588	0.3272 ± 0.8103	0.1211 ± 0.2111
	Range	0.0050 - 1.5900	0.0010 - 2.8100	0.0050 - 4.6230	0.0008 - 1.1300
DDD	Mean±Sd	0.0669 ± 0.1246	0.3049 ± 0.5258	0.2130 ± 0.5013	0.1001 ± 0.2306
	Range	0.0050 - 0.4700	0.0050 - 1.8150	0.0050 - 2.3000	0.0050 - 1.1200
DDT	Mean±Sd	0.0912 ± 0.1740	0.1129 ± 0.3060	0.1038 ± 0.1796	0.1416 ± 0.4861
	Range	0.0050 - 0.6100	0.0050 - 1.2700	0.0050 - 0.8440	0.0020 - 3.4560
Heptachlor	Mean±Sd	0.0050 ± 0.0000	0.0055 ± 0.0022	0.0050 ± 0.0000	0.0058 ± 0.0055
	Range	0.0050 - 0.0050	0.0050 - 0.0160	0.0050 - 0.0050	0.0050 - 0.0450
Endosulfan	Mean±Sd	0.4986 ± 1.3950	0.5920 ± 1.5645	0.2572 ± 0.8646	0.0503 ± 0.1577
	Range	0.0050 - 5.5700	0.0050 - 7.3540	0.0030 - 3.7530	0.0010 - 0.8100
Mercapthion	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0147 ± 0.0276	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.1000	0.0050 - 0.0050
Diazinon	Mean±Sd	0.0141 ± 0.0150	0.0085 ± 0.0174	0.0103 ± 0.0159	0.0167 ± 0.0342
	Range	0.0050 - 0.0600	0.0050 - 0.0900	0.0050 - 0.0800	0.0050 - 0.2000
Pirimiphos	Mean±Sd	0.0050 ± 0.0000	0.0085 ± 0.0174	0.0075 ± 0.0146	0.0152 ± 0.0602
	Range	0.0050 - 0.0050	0.0050 - 0.0900	0.0050 - 0.0900	0.0050 - 0.4300
Aldrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0158 ± 0.0790
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.5800
Endrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Atrazine	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005

Appendix D5: cont.

Crocodile		Montrose (n=2)		Croc hot (n=14)		Lions (n=20)		Rivuletts (n=6)	
BHC	Mean ± Sd	0.0005 ±	0.0000	0.0162 ±	0.0587	0.0130 ±	0.0558	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.2200	0.0005 -	0.2500	0.0005 -	0.0005
Lindane	Mean ± Sd	0.0450 ±	0.0170	0.0761 ±	0.0737	0.0871 ±	0.1405	0.0920 ±	0.0958
	Range	0.0330 -	0.0570	0.0050 -	0.2060	0.0030 -	0.4800	0.0050 -	0.2200
Dieldrin	Mean ± Sd	0.0005 ±	0.0000	0.0019 ±	0.0052	0.0030 ±	0.0077	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0200	0.0005 -	0.0300	0.0005 -	0.0005
DDE	Mean ± Sd	0.1230 ±	0.0339	0.1164 ±	0.1318	0.3359 ±	0.8135	0.0997 ±	0.0660
	Range	0.0990 -	0.1470	0.0050 -	0.4700	0.0050 -	3.1500	0.0080 -	0.1700
DDD	Mean ± Sd	0.0050 ±	0.0000	0.4285 ±	1.4227	0.1089 ±	0.2036	0.0320 ±	0.0627
	Range	0.0050 -	0.0050	0.0050 -	5.3670	0.0050 -	0.6900	0.0050 -	0.1600
DDT	Mean ± Sd	0.0050 ±	0.0000	0.2764 ±	0.9288	0.0853 ±	0.1863	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	3.4990	0.0050 -	0.7100	0.0050 -	0.0050
Heptachlor	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean ± Sd	0.0050 ±	0.0000	0.0068 ±	0.0067	0.0068 ±	0.0078	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0300	0.0050 -	0.0400	0.0050 -	0.0050
Mercapthion	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0175 ±	0.0201	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0700	0.0050 -	0.0050
Pirimiphos	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0093 ±	0.0190	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050
Aldrin	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean ± Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D5: cont.

Letaba		Junction (n=19)		Prieska (n=22)		Pumpst (n=16)		Slab (n=14)	
BHC	Mean±Sd	0.0199 ±	0.0555	0.0199 ±	0.0555	0.0110 ±	0.0230	0.0005 ±	0.0000
	Range	0.0005 -	0.2300	0.0005 -	0.2300	0.0005 -	0.0700	0.0005 -	0.0005
Lindane	Mean±Sd	0.2216 ±	0.2755	0.2216 ±	0.2755	0.3493 ±	0.3993	0.1431 ±	0.2087
	Range	0.0050 -	0.9100	0.0050 -	0.9100	0.0050 -	1.0100	0.0050 -	0.8000
Dieldrin	Mean±Sd	0.0037 ±	0.0101	0.0037 ±	0.0101	0.0020 ±	0.0041	0.0008 ±	0.0009
	Range	0.0005 -	0.0400	0.0005 -	0.0400	0.0005 -	0.0130	0.0005 -	0.0040
DDE	Mean±Sd	0.7311 ±	0.9692	0.7311 ±	0.9692	0.9509 ±	1.3813	1.1435 ±	1.2176
	Range	0.0280 -	3.9400	0.0280 -	3.9400	0.0070 -	5.4500	0.0490 -	3.3500
DDD	Mean±Sd	1.0013 ±	0.8958	1.0013 ±	0.8958	1.4884 ±	1.4989	2.9262 ±	4.2761
	Range	0.0410 -	2.6100	0.0410 -	2.6100	0.0020 -	5.3380	0.3500 -	13.1180
DDT	Mean±Sd	1.3031 ±	1.1681	1.3031 ±	1.1681	1.4024 ±	1.5337	2.6585 ±	4.2934
	Range	0.0340 -	3.7220	0.0340 -	3.7220	0.0050 -	4.8800	0.0050 -	15.0440
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D5: cont.

Letaba		Engelbrd (n=4)	Camp16 (n=1)	Hudson (n=4)	Midlet (n=1)
BHC	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0010 ± 0.0000	0.0010 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0010 - 0.0010	0.0010 - 0.0010
Lindane	Mean±Sd	0.1560 ± 0.0416	0.0050 ± 0.0000	0.1910 ± 0.3217	0.0050 ± 0.0000
	Range	0.0940 - 0.1800	0.0050 - 0.0050	0.0140 - 0.6730	0.0050 - 0.0050
Dieldrin	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005
DDE	Mean±Sd	0.3475 ± 0.0640	0.2200 ± 0.0000	2.0033 ± 1.5123	0.3130 ± 0.0000
	Range	0.2600 - 0.4000	0.2200 - 0.2200	0.1460 - 3.8500	0.3130 - 0.3130
DDD	Mean±Sd	0.3753 ± 0.3109	0.1400 ± 0.0000	1.7833 ± 0.9721	0.1170 ± 0.0000
	Range	0.2000 - 0.8410	0.1400 - 0.1400	0.3680 - 2.5650	0.1170 - 0.1170
DDT	Mean±Sd	0.3675 ± 0.1438	0.1100 ± 0.0000	0.6033 ± 0.8022	0.0270 ± 0.0000
	Range	0.1900 - 0.5300	0.1100 - 0.1100	0.1350 - 1.8040	0.0270 - 0.0270
Heptachlor	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endosulfan	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Mercapthion	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Diazinon	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Pirimiphos	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Aldrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Atrazine	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005

Appendix D5: cont.

Luvuvhu		Mkyaupst (n=4)		Settlement (n=1)		Mkunya (n=1)		Farm (n=2)	
BHC	Mean±Sd	0.0006 ±	0.0003	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0008 ±	0.0004
	Range	0.0005 -	0.0010	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0010
Lindane	Mean±Sd	0.0163 ±	0.0225	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0225 ±	0.0247
	Range	0.0050 -	0.0500	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0400
Dieldrin	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.5250 ±	0.4417	0.3300 ±	0.0000	1.3700 ±	0.0000	0.1650 ±	0.2192
	Range	0.0700 -	1.1200	0.3300 -	0.3300	1.3700 -	1.3700	0.0100 -	0.3200
DDD	Mean±Sd	0.1740 ±	0.1080	5.8400 ±	0.0000	1.2800 ±	0.0000	0.1275 ±	0.1732
	Range	0.0360 -	0.2600	5.8400 -	5.8400	1.2800 -	1.2800	0.0050 -	0.2500
DDT	Mean±Sd	0.0525 ±	0.0555	0.1680 ±	0.0000	1.4000 ±	0.0000	0.0625 ±	0.0813
	Range	0.0050 -	0.1100	0.1680 -	0.1680	1.4000 -	1.4000	0.0050 -	0.1200
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D5: cont.

Olifants		Loskop (n=6)		Vyeboom (n=1)		Baluli (n=6)		Mamba Weir (n=12)		Selati (n=2)		Arabie (n=18)	
BHC	Mean±Sd	0.0538 ±	0.1304	0.0005 ±	0.0000	0.0006 ±	0.0002	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0012 ±	0.0027
	Range	0.0005 -	0.3200	0.0005 -	0.0005	0.0005 -	0.0010	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0120
Lindane	Mean±Sd	0.1683 ±	0.0214	0.0050 ±	0.0000	0.1205 ±	0.2187	0.0128 ±	0.0156	0.0235 ±	0.0247	0.1428 ±	0.3129
	Range	0.1500 -	0.2100	0.0050 -	0.0050	0.0040 -	0.5640	0.0040 -	0.0510	0.0060 -	0.0410	0.0050 -	1.1300
Dieldrin	Mean±Sd	0.0038 ±	0.0080	0.0005 ±	0.0000	0.0018 ±	0.0015	0.0012 ±	0.0010	0.0005 ±	0.0000	0.0008 ±	0.0013
	Range	0.0005 -	0.0200	0.0005 -	0.0005	0.0005 -	0.0040	0.0005 -	0.0030	0.0005 -	0.0005	0.0005 -	0.0060
DDE	Mean±Sd	0.2533 ±	0.2193	0.0330 ±	0.0000	0.2733 ±	0.6514	0.4200 ±	0.8145	0.0690 ±	0.0255	0.3267 ±	0.4102
	Range	0.1500 -	0.7000	0.0330 -	0.0330	0.0040 -	1.6030	0.0050 -	2.3550	0.0510 -	0.0870	0.0010 -	1.4200
DDD	Mean±Sd	0.0475 ±	0.1041	0.0200 ±	0.0000	0.1857 ±	0.3404	0.3212 ±	0.6283	0.0540 ±	0.0269	0.1656 ±	0.2234
	Range	0.0050 -	0.2600	0.0200 -	0.0200	0.0050 -	0.8620	0.0050 -	2.0910	0.0350 -	0.0730	0.0050 -	0.7000
DDT	Mean±Sd	0.0308 ±	0.0633	0.0050 ±	0.0000	0.0395 ±	0.0539	1.2888 ±	3.5298	0.0065 ±	0.0021	0.0119 ±	0.0147
	Range	0.0050 -	0.1600	0.0050 -	0.0050	0.0050 -	0.1200	0.0050 -	12.2500	0.0050 -	0.0080	0.0050 -	0.0600
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D5: cont.

Olifants		Arabie (n=18)		Preselati (n=2)		Pierneef (n=3)		Postselati (n=6)		Klipspruit (n=5)		Meetwal (n=4)	
BHC	Mean ± Sd	0.0012 ±	0.0027	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0010 ±	0.0000
	Range	0.0005 -	0.0120	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0010 -	0.0010
Lindane	Mean ± Sd	0.1428 ±	0.3129	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0127 ±	0.0129	0.0050 ±	0.0000	0.0360 ±	0.0230
	Range	0.0050 -	1.1300	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0360	0.0050 -	0.0050	0.0130 -	0.0600
Dieldrin	Mean ± Sd	0.0008 ±	0.0013	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0060	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean ± Sd	0.3267 ±	0.4102	0.7200 ±	0.3394	0.0680 ±	0.1091	0.8547 ±	1.5620	0.0050 ±	0.0000	0.6073 ±	0.6471
	Range	0.0010 -	1.4200	0.4800 -	0.9600	0.0050 -	0.1940	0.0050 -	3.9900	0.0050 -	0.0050	0.0970 -	1.5010
DDD	Mean ± Sd	0.1656 ±	0.2234	0.4000 ±	0.2121	0.0050 ±	0.0000	0.8675 ±	1.6916	0.0050 ±	0.0000	1.0033 ±	0.9058
	Range	0.0050 -	0.7000	0.2500 -	0.5500	0.0050 -	0.0050	0.0050 -	4.2700	0.0050 -	0.0050	0.0590 -	1.8900
DDT	Mean ± Sd	0.0119 ±	0.0147	0.3400 ±	0.1838	0.0050 ±	0.0000	0.2275 ±	0.3847	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0600	0.2100 -	0.4700	0.0050 -	0.0050	0.0050 -	1.0000	0.0050 -	0.0050	0.0050 -	0.0050
Heptachlor	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean ± Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean ± Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D5: cont.

Sabie Weir (n=18)			
BHC	Mean±Sd	0.0008 ±	0.0003
	Range	0.0005 -	0.0010
Lindane	Mean±Sd	0.0248 ±	0.0516
	Range	0.0020 -	0.2210
Dieldrin	Mean±Sd	0.0005 ±	0.0000
	Range	0.0005 -	0.0005
DDE	Mean±Sd	0.2979 ±	0.4063
	Range	0.0100 -	1.5400
DDD	Mean±Sd	0.6402 ±	0.5860
	Range	0.0300 -	1.7100
DDT	Mean±Sd	0.1199 ±	0.1987
	Range	0.0050 -	0.7400
Heptachlor	Mean±Sd	0.0050 ±	0.0000
	Range	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000
	Range	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000
	Range	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000
	Range	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000
	Range	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000
	Range	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000
	Range	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000
	Range	0.0005 -	0.0005

Appendix D6 : The number, mean, standard deviation and range of the pesticides analyzed for different rivers per species.

Berg		*O. mossambicus* (n=9)		*C. carpio* (n=9)		*M. dolomieu* (n=1)	
BHC	Mean±Sd	0.0005 ±	0.0000	0.0006 ±	0.0002	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0010	0.0005 -	0.0005
Lindane	Mean±Sd	0.0371 ±	0.0375	0.0347 ±	0.0463	0.0050 ±	0.0000
	Range	0.0050 -	0.1000	0.0020 -	0.1500	0.0050 -	0.0050
Dieldrin	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.0716 ±	0.0516	0.0390 ±	0.0374	0.0200 ±	0.0000
	Range	0.0130 -	0.1800	0.0050 -	0.1100	0.0200 -	0.0200
DDD	Mean±Sd	0.0467 ±	0.0441	0.0314 ±	0.0505	0.1500 ±	0.0000
	Range	0.0050 -	0.1300	0.0050 -	0.1600	0.1500 -	0.1500
DDT	Mean±Sd	0.0068 ±	0.0046	0.0101 ±	0.0142	0.0050 ±	0.0000
	Range	0.0050 -	0.0190	0.0050 -	0.0480	0.0050 -	0.0050
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.1148 ±	0.2683	0.0203 ±	0.0257	0.0005 ±	0.0000
	Range	0.0005 -	0.8200	0.0005 -	0.0700	0.0005 -	0.0005

Appendix D6: cont.

Crocodile		*O. mossambicus* (n=19)		*L. molybdinus* (n=28)		*B. marequensis* (n=44)		*H. vittatus* (n=5)		*C. gariepinus* (n=55)		*L. rosae* (n=6)	
BHC	Mean±Sd	0.0022 ±	0.0075	0.0033 ±	0.0116	0.0109 ±	0.0413	0.0100 ±	0.0212	0.0129 ±	0.0520	0.0005 ±	0.0000
	Range	0.0005 -	0.0330	0.0005 -	0.0600	0.0005 -	0.2100	0.0005 -	0.0480	0.0005 -	0.2500	0.0005 -	0.0005
Lindane	Mean±Sd	0.0722 ±	0.1259	1.0743 ±	3.0934	0.0813 ±	0.1492	1.1150 ±	1.4560	0.1079 ±	0.1753	0.0233 ±	0.0191
	Range	0.0010 -	0.4200	0.0050 -	12.2700	0.0040 -	0.8500	0.0050 -	3.1200	0.0004 -	0.9600	0.0040 -	0.0450
Dieldrin	Mean±Sd	0.0120 ±	0.0344	0.0005 ±	0.0000	0.0011 ±	0.0031	0.0174 ±	0.0378	0.0022 ±	0.0059	0.0014 ±	0.0022
	Range	0.0005 -	0.1200	0.0005 -	0.0005	0.0005 -	0.0200	0.0005 -	0.0850	0.0005 -	0.0300	0.0005 -	0.0060
DDE	Mean±Sd	0.0811 ±	0.1912	0.1307 ±	0.1936	0.3504 ±	0.8151	0.2874 ±	0.4754	0.2935 ±	0.6368	0.3358 ±	0.4055
	Range	0.0008 -	0.8300	0.0020 -	0.7600	0.0040 -	4.6230	0.0050 -	1.1300	0.0010 -	3.1500	0.0050 -	1.0960
DDD	Mean±Sd	0.0453 ±	0.1018	0.1265 ±	0.4361	0.2333 ±	0.8545	0.5500 ±	0.5385	0.1843 ±	0.3734	0.0858 ±	0.1275
	Range	0.0050 -	0.4320	0.0050 -	2.3000	0.0050 -	5.3670	0.0050 -	1.1200	0.0050 -	1.8150	0.0050 -	0.3100
DDT	Mean±Sd	0.0409 ±	0.0624	0.0732 ±	0.1610	0.1441 ±	0.5479	0.9330 ±	1.4407	0.1058 ±	0.2295	0.0512 ±	0.0680
	Range	0.0050 -	0.2120	0.0050 -	0.5500	0.0050 -	3.4990	0.0050 -	3.4560	0.0050 -	1.2700	0.0050 -	0.1800
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0054 ±	0.0021	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0117 ±	0.0163
	Range	0.0050 -	0.0050	0.0050 -	0.0160	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0450
Endosulfan	Mean±Sd	0.0461 ±	0.1461	0.8198 ±	1.8239	0.2258 ±	0.9430	0.0050 ±	0.0000	0.1309 ±	0.5136	0.1455 ±	0.2103
	Range	0.0010 -	0.6300	0.0050 -	7.3540	0.0050 -	5.1100	0.0050 -	0.0050	0.0030 -	3.3300	0.0050 -	0.5130
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0100 ±	0.0188	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0067 ±	0.0128	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.1000	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0126 ±	0.0208	0.0113 ±	0.0166	0.0106 ±	0.0150	0.0050 ±	0.0000	0.0129 ±	0.0175	0.0050 ±	0.0000
	Range	0.0050 -	0.0800	0.0050 -	0.0800	0.0050 -	0.0700	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0111 ±	0.0264	0.0080 ±	0.0161	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0081 ±	0.0161	0.0050 ±	0.0000
	Range	0.0050 -	0.1200	0.0050 -	0.0900	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0900	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0353 ±	0.1319	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.5800	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D6: cont.

Crocodile		*T. rendalli* (n=19)	*S. zambezensis* (n=1)	*L. congoro* (n=6)	*B. imberi* (n=1)	*S. intermedius* (n=1)
BHC	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0466 ± 0.0864	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.2100	0.0005 - 0.0005	0.0005 - 0.0005
Lindane	Mean±Sd	0.0872 ± 0.1391	0.0100 ± 0.0000	0.1388 ± 0.0753	0.1700 ± 0.0000	0.1600 ± 0.0000
	Range	0.0050 - 0.4100	0.0100 - 0.0100	0.0200 - 0.2400	0.1700 - 0.1700	0.1600 - 0.1600
Dieldrin	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0029 ± 0.0069	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0200	0.0005 - 0.0005	0.0005 - 0.0005
DDE	Mean±Sd	0.0951 ± 0.1462	0.0400 ± 0.0000	0.1875 ± 0.0892	0.1700 ± 0.0000	0.1800 ± 0.0000
	Range	0.0020 - 0.5300	0.0400 - 0.0400	0.0300 - 0.3500	0.1700 - 0.1700	0.1800 - 0.1800
DDD	Mean±Sd	0.0771 ± 0.1192	0.0200 ± 0.0000	0.0738 ± 0.0772	0.2000 ± 0.0000	0.1700 ± 0.0000
	Range	0.0050 - 0.4000	0.0200 - 0.0200	0.0050 - 0.1700	0.2000 - 0.2000	0.1700 - 0.1700
DDT	Mean±Sd	0.0836 ± 0.1487	0.0200 ± 0.0000	0.0706 ± 0.0920	0.1600 ± 0.0000	0.1600 ± 0.0000
	Range	0.0020 - 0.6000	0.0200 - 0.0200	0.0050 - 0.2100	0.1600 - 0.1600	0.1600 - 0.1600
Heptachlor	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endosulfan	Mean±Sd	0.0475 ± 0.1846	0.0050 ± 0.0000	0.0081 ± 0.0088	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.8100	0.0050 - 0.0050	0.0050 - 0.0300	0.0050 - 0.0050	0.0050 - 0.0050
Mercapthion	Mean±Sd	0.0100 ± 0.0218	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.1000	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Diazinon	Mean±Sd	0.0284 ± 0.0512	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.2000	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Pirimiphos	Mean±Sd	0.0274 ± 0.0975	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.4300	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Aldrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Atrazine	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005

Appendix D6: cont.

Letaba		*O. mossambicus* (n=34)	*L. molybdinus* (n=7)	*B. marequensis* (n=4)	*C. gariepinus* (n=26)	*L. rosae* (n=5)	*S. intermedius* (n=5)
BHC	Mean±Sd	0.0111 ± 0.0418	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0047 ± 0.0149	0.0146 ± 0.0310	0.0005 ± 0.0000
	Range	0.0005 - 0.2300	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0600	0.0005 - 0.0700	0.0005 - 0.0005
Dieldrin	Mean±Sd	0.1757 ± 0.2589	0.1631 ± 0.0560	0.3465 ± 0.3516	0.1810 ± 0.3057	0.4550 ± 0.4034	0.0990 ± 0.1355
	Range	0.0050 - 1.0100	0.0390 - 0.2030	0.0160 - 0.8300	0.0020 - 0.9100	0.0050 - 0.7900	0.0050 - 0.3000
Lindane	Mean±Sd	0.0024 ± 0.0072	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0016 ± 0.0043	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0400	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0220	0.0005 - 0.0005	0.0005 - 0.0005
DDE	Mean±Sd	0.5162 ± 0.5518	0.5981 ± 0.2591	0.9898 ± 1.1402	1.3259 ± 1.3357	3.1024 ± 1.7202	0.3320 ± 0.2543
	Range	0.0070 - 2.2000	0.2720 - 0.9000	0.0490 - 2.6000	0.0170 - 3.9400	0.9800 - 5.4500	0.1200 - 0.7500
DDD	Mean±Sd	1.1468 ± 1.1538	0.5637 ± 0.3191	0.6965 ± 0.3364	3.0286 ± 4.6024	2.8012 ± 2.0925	0.3968 ± 0.4128
	Range	0.0020 - 5.3380	0.1800 - 1.0460	0.2000 - 0.9460	0.0400 - 18.0760	0.8200 - 6.3520	0.1100 - 1.1100
DDT	Mean±Sd	1.1840 ± 1.2725	0.6536 ± 0.2082	0.4888 ± 0.3943	2.0115 ± 3.4085	1.1826 ± 1.1101	0.6270 ± 0.9492
	Range	0.0050 - 4.8800	0.3700 - 0.9200	0.0050 - 0.8300	0.0050 - 15.0440	0.2120 - 2.7590	0.1100 - 2.3100
Heptachlor	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endosulfan	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Mercapthion	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Diazinon	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Pirimiphos	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Aldrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Atrazine	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005

Appendix D6: cont.

Luvuvhu		*O. mossambicus* (n=1)		*H. vittatus* (n=1)		*C. gariepinus* (n=1)		*L. rosae* (n=2)		*L. congoro* (n=2)	
BHC	Mean±Sd	0.0010 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0008 ±	0.0004
	Range	0.0010 -	0.0010	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0010
Lindane	Mean±Sd	0.0400 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0275 ±	0.0318
	Range	0.0400 -	0.0400	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0500
Dieldrin	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.3200 ±	0.0000	1.3700 ±	0.0000	0.3300 ±	0.0000	0.2200 ±	0.2121	0.8300 ±	0.4101
	Range	0.3200 -	0.3200	1.3700 -	1.3700	0.3300 -	0.3300	0.0700 -	0.3700	0.5400 -	1.1200
DDD	Mean±Sd	0.2500 ±	0.0000	1.2800 ±	0.0000	5.8400 ±	0.0000	0.0880 ±	0.0735	0.2600 ±	0.0000
	Range	0.2500 -	0.2500	1.2800 -	1.2800	5.8400 -	5.8400	0.0360 -	0.1400	0.2600 -	0.2600
DDT	Mean±Sd	0.1200 ±	0.0000	1.4000 ±	0.0000	0.1680 ±	0.0000	0.0050 ±	0.0000	0.1000 ±	0.0141
	Range	0.1200 -	0.1200	1.4000 -	1.4000	0.1680 -	0.1680	0.0050 -	0.0050	0.0900 -	0.1100
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D6: cont.

Olifants		*O. mossambicus* (n=7)	*C. carpio* (n=1)	*B. marequensis* (n=3)	*C. gariepinus* (n=40)
BHC	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0009 ± 0.0018
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0120
Lindane	Mean±Sd	0.2187 ± 0.4047	0.0050 ± 0.0000	0.0047 ± 0.0006	0.0601 ± 0.1568
	Range	0.0100 - 1.1300	0.0050 - 0.0050	0.0040 - 0.0050	0.0040 - 0.8300
Dieldrin	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0010 ± 0.0009	0.0010 ± 0.0012
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0020	0.0005 - 0.0060
DDE	Mean±Sd	0.3740 ± 0.3699	0.0200 ± 0.0000	0.0047 ± 0.0006	0.4597 ± 0.8292
	Range	0.0010 - 0.9400	0.0200 - 0.0200	0.0040 - 0.0050	0.0040 - 3.9900
DDD	Mean±Sd	0.2511 ± 0.2744	0.0050 ± 0.0000	0.0050 ± 0.0000	0.3878 ± 0.8219
	Range	0.0050 - 0.7000	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 4.2700
DDT	Mean±Sd	0.0114 ± 0.0099	0.0050 ± 0.0000	0.0050 ± 0.0000	0.4816 ± 1.9616
	Range	0.0050 - 0.0300	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 12.2500
Heptachlor	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endosulfan	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Mercapthion	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Diazinon	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Pirimiphos	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Aldrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Endrin	Mean±Sd	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000	0.0050 ± 0.0000
	Range	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050	0.0050 - 0.0050
Atrazine	Mean±Sd	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000	0.0005 ± 0.0000
	Range	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005	0.0005 - 0.0005

Appendix D6: cont.

Olifants		*L. rosae* (n=8)		*L. congoro* (n=5)		****Sd(n=1)	
BHC	Mean±Sd	0.0006 ±	0.0002	0.0646 ±	0.1428	0.0005 ±	0.0000
	Range	0.0005 -	0.0010	0.0005 -	0.3200	0.0005 -	0.0005
Lindane	Mean±Sd	0.0499 ±	0.0662	0.0516 ±	0.0887	0.1700 ±	0.0000
	Range	0.0050 -	0.1600	0.0050 -	0.2100	0.1700 -	0.1700
Dieldrin	Mean±Sd	0.0005 ±	0.0000	0.0044 ±	0.0087	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0200	0.0005 -	0.0005
DDE	Mean±Sd	0.1576 ±	0.1028	0.1978 ±	0.2881	0.1900 ±	0.0000
	Range	0.0050 -	0.3400	0.0050 -	0.7000	0.1900 -	0.1900
DDD	Mean±Sd	0.0499 ±	0.0518	0.1448 ±	0.1250	0.0050 ±	0.0000
	Range	0.0050 -	0.1500	0.0050 -	0.2600	0.0050 -	0.0050
DDT	Mean±Sd	0.0050 ±	0.0000	0.0738 ±	0.0719	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.1600	0.0050 -	0.0050
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D6: cont.

Sabie		*O. mossambicus* (n=1)		*B. marequensis* (n=7)		*H. vittatus* (n=1)		*C. gariepinus* (n=1)		*L. rosae* (n=3)	
BHC	Mean±Sd	0.0010 ±	0.0000	0.0009 ±	0.0002	0.0010 ±	0.0000	0.0005 ±	0.0000	0.0007 ±	0.0003
	Range	0.0010 -	0.0010	0.0005 -	0.0010	0.0010 -	0.0010	0.0005 -	0.0005	0.0005 -	0.0010
Lindane	Mean±Sd	0.0130 ±	0.0000	0.0143 ±	0.0247	0.0310 ±	0.0000	0.0050 ±	0.0000	0.0160 ±	0.0122
	Range	0.0130 -	0.0130	0.0020 -	0.0700	0.0310 -	0.0310	0.0050 -	0.0050	0.0080 -	0.0300
Dieldrin	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.1230 ±	0.0000	0.1669 ±	0.2377	0.2770 ±	0.0000	0.0100 ±	0.0000	0.1993 ±	0.1617
	Range	0.1230 -	0.1230	0.0120 -	0.6800	0.2770 -	0.2770	0.0100 -	0.0100	0.0680 -	0.3800
DDD	Mean±Sd	0.7310 ±	0.0000	0.5780 ±	0.6041	1.5810 ±	0.0000	0.0300 ±	0.0000	0.4733 ±	0.4579
	Range	0.7310 -	0.7310	0.0840 -	1.7000	1.5810 -	1.5810	0.0300 -	0.0300	0.1700 -	1.0000
DDT	Mean±Sd	0.1580 ±	0.0000	0.0180 ±	0.0238	0.3640 ±	0.0000	0.0100 ±	0.0000	0.0160 ±	0.0149
	Range	0.1580 -	0.1580	0.0050 -	0.0700	0.3640 -	0.3640	0.0100 -	0.0100	0.0050 -	0.0330
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	·0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix D6: cont.

Sabie		*L. congoro* (n=3)		*S. intermedius* (n=1)		*L. ruddi* (n=1)	
BHC	Mean±Sd	0.0008 ±	0.0003	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0010	0.0005 -	0.0005	0.0005 -	0.0005
Lindane	Mean±Sd	0.0780 ±	0.1239	0.0100 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.2210	0.0100 -	0.0100	0.0050 -	0.0050
Dieldrin	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005
DDE	Mean±Sd	0.8653 ±	0.7302	0.0500 ±	0.0000	0.5400 ±	0.0000
	Range	0.0900 -	1.5400	0.0500 -	0.0500	0.5400 -	0.5400
DDD	Mean±Sd	0.9350 ±	0.7730	0.0500 ±	0.0000	0.8600 ±	0.0000
	Range	0.1640 -	1.7100	0.0500 -	0.0500	0.8600 -	0.8600
DDT	Mean±Sd	0.2273 ±	0.1761	0.0300 ±	0.0000	0.7400 ±	0.0000
	Range	0.0480 -	0.4000	0.0300 -	0.0300	0.7400 -	0.7400
Heptachlor	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endosulfan	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Mercapthion	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Diazinon	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Pirimiphos	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Aldrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Endrin	Mean±Sd	0.0050 ±	0.0000	0.0050 ±	0.0000	0.0050 ±	0.0000
	Range	0.0050 -	0.0050	0.0050 -	0.0050	0.0050 -	0.0050
Atrazine	Mean±Sd	0.0005 ±	0.0000	0.0005 ±	0.0000	0.0005 ±	0.0000
	Range	0.0005 -	0.0005	0.0005 -	0.0005	0.0005 -	0.0005

Appendix E
Pesticide usage on crops

Appendix E: Pesticide usage for the Berg River.

Berg	Forest	Grapes -Appendix	Grapes -wine	Wheat	Total
2.4-D	0	0	0	0.416	0.416
2.4-DAMINE	0	0	0	0.958	0.958
2.4-DESTER	0	0	0	0.600	0.600
ACEPHATE	0	0	0.556	0	0.556
ACETOCHLOR	1.801	0	0	0	1.801
ALDICARB	0	3.721	3.747	0	7.469
ALPHACYPERMETHRIN	0.004	0.010	0	0	0.014
AMITROLE	0	1.591	1.640	0	3.231
BENOMYL	0	0.250	0.225	0	0.475
BITERTANOL	0	0	0	0.007	0.007
BROMOPROPYLATE	0	0.025	0.025	0	0.050
BROMOXYNIL	0	0	0	0.422	0.422
CAPTAN	0	1.000	0	0	1.000
CARBARYL	0	0.821	0.799	0	1.620
CARBOSULFAN	4.127	0	0	0	4.127
CARBOXIN	0	0	0	0.026	0.026
CGA-184927	0	0	0	0.049	0.049
CHLORDANE	2.635	2.000	1.946	0	6.581
CHLORMEQUAT	0	0	0	1.600	1.600
CHLORPYRIFOS	0.475	0.480	0.480	0.360	1.795
CHLORSULFURON	0	0	0	0.006	0.006
COPPER-HYDROXIDE	0	1.538	0	0	1.538
COPPER-OXYCHLORIDE	0	3.404	3.400	0	6.804
COPPER-SULPHATE	0	1.543	1.700	0	3.243
CYANAMIDE	0	4.900	0	0	4.900
CYCLOXYDIM	0	0.185	0.194	0	0.380
CYFLUTHRIN	0	0.011	0.011	0	0.022
CYHALOTHRIN-L	0.003	0	0.020	0	0.024
CYMOXANIL	0	0.115	0.097	0	0.212
CYPERMETHRIN	0.010	0.019	0.020	0	0.050
CYTOKININ	0	0	0	0.061	0.061
DELTAMETHRIN	0	0.008	0.010	0.012	0.030
DEMETON-S-M	0	0	0	0.125	0.125
DICHLOFLUANID	0	0.854	0	0	0.854
DICHLORVOS	0	3.753	3.727	0.200	7.681
DICLOFOP-M	0	0	0	0.333	0.333
DIMETHOATE	0	0	0	0.384	0.384
DINOCAP	0	0.115	0.343	0	0.458
DIQUAT	0	0.319	0.452	0	0.770
ENDOSULFAN	0	0.362	0.360	0	0.722
ETHEPHON	0	0.194	0	0.480	0.674
FENAMINOSULF	0	0	0	0.013	0.013
FENAMIPHOS	0	3.981	3.835	0	7.816
FENOXAPROP-E	0	0	0	0.054	0.054
FENTHION	0	1.158	0.636	0	1.794
FENVALERATE	0	0.038	0.036	0	0.074
FLAMPROP-M-I	0	0	0	0.600	0.600
FLUAZIFOP-B	0.375	0.370	0.374	0	1.119
FLUSILAZOLE	0	0.018	0.021	0	0.039
FLUTRIAFOL	0	0	0	0.002	0.002
FOLPET	0	0.752	0.752	0	1.504
FORMOTHION	0	1.627	1.635	0	3.262
FOSETYL-AL	0	1.324	1.323	0	2.647

Berg	Forest	Grapes -Appendix	Grapes -wine	Wheat	Total
GIBBERELLIC-ACID	0	0.453	0	0	0.453
GLYPHOSATE	1.440	0.672	0.890	0	3.002
GUAZATINE	0	0	0	0.080	0.080
HALOXYFOP-ETHOXYETHYL	0	0.429	0.367	0	0.795
HEXACONAZOLE	0	0.011	0.011	0	0.022
IMAZAMETHABENZ	0	0	0	0.750	0.750
IMAZAPYR	2.500	0	0	0	2.500
IPRODIONE	0	0.505	0.500	0	1.005
ISOXABEN	0	0	0	0.075	0.075
LIME-SULPHUR	0	4.421	0	0	4.421
LINDANE	0.059	0	0	0	0.059
MANCOZEB	0	1.379	1.380	0.060	2.818
MCPA	0	0	2.000	0.858	2.858
METALAXYL	0	0.250	0.241	0	0.491
METALDEHYDE	0	1.214	1.201	0	2.415
METHIDATHION	0	2.100	2.069	0	4.169
METHIOCARB	0	0.778	0.799	0	1.577
METOLACHLOR	1.921	0	0	0	1.921
METSULFURON-M	0	0	0	0.011	0.011
MONOCROTOPHOS	0	0	0	0.214	0.214
MYCLOBUTANIL	0	0.020	0.023	0	0.042
NUARIMOL	0	0.011	0.010	0	0.021
OFURACE	0	0	0.120	0	0.120
OMETHOATE	0	2.368	0	0	2.368
ORYZALIN	0	1.700	1.667	0	3.367
OXADIAZON	0	1.167	1.226	0	2.393
OXADIXYL	0	0.226	0.231	0	0.457
OXYFLUORFEN	0.721	0	0	0	0.721
PARAQUAT	0.500	0.475	0.488	0.304	1.767
PARATHION-E	0	0	0	0.325	0.325
PENCONAZOLE	0	0.034	0.034	0	0.068
PICLORAM	0	0	0	0.018	0.018
POLYSULFIDES-CA	0	12.761	12.803	0	25.563
PROCYMIDONE	0	0.500	0.500	0	1.000
PROPINEB	0	1.135	1.120	0	2.255
PROPOXUR	0	0.390	0	0	0.390
PROTEINHYDROLISATE	0	0.188	0	0	0.188
PROTHIOFOS	0	2.411	2.404	0	4.815
PYRIFENOX	0	0.044	0.043	0	0.087
SIMAZINE	0	1.512	1.531	0	3.043
SULPHUR	0	14.722	15.145	0	29.867
TEBUCONAZOLE	2.400	0	0	0.002	2.402
THIABENDAZOLE	0	0	0	0.002	0.002
THIFENSULFURON-M	0	0	0	0.002	0.002
THIOMETON	0	0	0	0.138	0.138
THIRAM	0	0	0	0.026	0.026
TRALKOXYDIM	0	0	0	0.189	0.189
TRALOMETHRIN	0	0	0.008	0	0.008
TRIADIMEFON	0	0.444	0.586	0.126	1.156
TRIADIMENOL	0	0.052	0.051	0.011	0.114
TRICHLORFON	0	0.047	0	0	0.047
TRICLOPYR	9.634	0	0	0	9.634
TRIFLURALIN	0	3.727	3.909	0	7.636
VINCLOZOLIN	0	0.478	0.502	0	0.981

Appendix E: Pesticide usage for the Crocodile River.

Crocodile	Forest	Bananas	Citrus	Corn	Sugar	Tobacco	Tomatoes	Total
2.4-DAMINE	0	0	0	0.270	0.427	0	0	0.696
2.4-DESTER	0	0	0	0.375	0	0	0	0.375
ACETOCHLOR	1.801	0	0	0.877	1.805	0	0	4.483
ALACHLOR	0	0	0	1.757	1.920	0	0	3.677
AMETRYN	0	3.216	0	0	1.304	0	0	4.520
ATRAZINE	0	0	0	1.125	1.258	0	0	2.384
BENTAZONE	0	0	0	1.670	1.957	0	0	3.627
BROMACIL	0	0	4.000	0	0	0	0	4.000
BROMOFENOXIM	0	0	0	0	0.500	0	0	0.500
BROMOXYNIL	0	0	0	0.244	0.235	0	0	0.479
BUTYLATE	0	0	0	2.699	0	0	0	2.699
CHLORIMURON-E	0	0	0	0	0.009	0	0	0.009
CLOMAZONE	0	0	0	0	0	0.958	0	0.958
CYANAZINE	0	0	0	0.949	3.059	0	0	4.008
CYCLOATE	0	0	0	2.161	2.868	0	0	5.029
CYCLOXYDIM	0	0	0.167	0	0.200	0.182	0.211	0.759
DICAMBA	0	0	0	0.241	0.122	0	0	0.362
DIPHENAMID	0	0	0	0	0	2.010	4.968	6.978
DIURON	0	3.167	3.139	0	1.980	0	0	8.286
EPTC	0	0	0	2.160	2.879	0	0	5.039
FLUAZIFOP-B	0.375	0.381	0.380	0	0.375	0	0	1.510
FLUOROCHLORID'N	0	0	0	0	0.625	0	0	0.625
FOMESAFEN	0	0	0	0	0.250	0	0	0.250
GLYPHOSATE	1.440	0.564	0.556	0.540	3.239	0	2.154	8.492
HEXAZINONE	0	0	0	0	0.753	0	0	0.753
IMAZAPYR	2.500	0	0	0	0	0	0	2.500
IMAZETHAPYR	0	0	0	0	0.040	0	0	0.040
IOXYNIL	0	0	0	0	0.219	0	0	0.219
LINURON	0	0	0	0	1.130	0	0	1.130
MCPA	0	0	0	1.000	0.972	0	0	1.972
METAZACHLOR	0	0	0	0.611	0.610	0.593	0	1.814
METOLACHLOR	1.921	0	0	0.798	0.546	1.396	0	4.662
METRIBUZIN	0	0	0	0	1.071	0	0.678	1.749
MSMA	0	0	0	0	2.160	0	0	2.160
NICOSULFURON	0	0	0	0.450	0	0	0	0.450
OXYFLUORFEN	0.721	0	0.700	0	0	0	0	1.421
PARAQUAT	0.500	0.400	0.602	0.300	0.450	0	0.600	2.852
PEBULATE	0	0	0	0	0	5.042	0	5.042
PENDIMETHALIN	0	0	0	0	1.250	1.002	0	2.252
PRIMISULFURON	0	0	0	0.010	0	0	0	0.010
PROPACHLOR	0	0	0	0	3.125	0	0	3.125
PROPAZINE	0	0	0	1.010	0	0	0	1.010
SETHOXYDIM	0	0	0	0	0.429	0	0	0.429
SIMAZINE	0	0	2.513	0.825	0	0	0	3.338
SULCITRIONE	0	0	0	0.149	0	0	0	0.149
TERBUTHYLAZINE	0	0	0	0.877	1.189	0	0	2.066
TRICLOPYR	9.634	0	0	0	0	0	0	9.634
TRIFLURALIN	0	0	0	0	0.624	0	0.727	1.351
ABAMECTIN	0	0	0	0	0	0	0.011	0.011
ACEPHATE	0	0	0	0	0.411	0.764	0	1.175
ALDICARB	0	5.994	8.239	1.492	5.258	3.000	3.008	26.992
ALPHACYPERMETH	0.004	0	0	0.007	0.007	0.005	0.007	0.031
AMITRAZ	0	0	1.200	0	0	0	0	1.200
ANILAZINE	0	0	0	0	0	0	1.504	1.504
AZINPHOS-M	0	0	0	0	0.279	0	0	0.279

Crocodile	Forest	Bananas	Citrus	Corn	Sugar	Tobacco	Tomatoes	Total
BACILLUS-THUR.	0	0	0.251	0	0	0	0	0.251
BENFURACARB	0	0	0	0.202	0.200	0	0	0.402
BENODANIL	0	0	0	0	0.181	0	0	0.181
BENOMYL	0	0.583	2.253	0	0.126	4.000	0.175	7.137
BIFENTHRIN	0	0	0	0	0.031	0	0.041	0.072
BROMOPROPYLATE	0	0.048	0.100	0	0	0	0	0.147
BUPROFEZIN	0	0	0.751	0	0	0	0	0.751
BUTRALIN	0	0	0	0	0	0.718	0	0.718
CALCIUMARSENAT	0	0	3.421	0	0	0	0	3.421
CAPTAN	0	0	0	0.019	0.026	2.611	1.000	3.656
CARBARYL	0	0.389	1.000	0.100	0	0.972	0	2.461
CARBENDAZIM	0	0	2.503	0	0	0	0	2.503
CARBOFURAN	0	0	0	1.660	1.298	1.989	0	4.947
CARBOSULFAN	4.127	0	0	2.009	0	0	0	6.137
CGA-133205	0	0	0	0	0.003	0	0	0.003
CHLORDANE	2.635	0	1.958	0	0	0	0	4.593
CHLOROPICRIN	0	0	0	0	0	47.791	0	47.791
CHLOROTHALONIL	0	0	0	0	1.000	0	1.000	2.000
CHLORPYRIFOS	0.475	0.360	0.943	0.223	0	0.864	0.480	3.344
CHLORTHAL	0	0	0	0	0	0.719	0	0.719
COPPER-HYDROXID	0	0	8.400	0	1.924	0	1.540	11.864
COPPER-OXYCHLR.	0	0	10.196	0	0	28.021	2.533	40.750
COPPER-SULPHATE	0	0	0	0	0	0	1.750	1.750
CUPRAMMONIUMCMP	0	0	0	0	0	0	3.250	3.250
CYFLUTHRIN	0	0	0	0.006	0.016	0	0.009	0.031
CYHALOTHRIN-L	0.003	0	0	0.004	0.003	0.003	0.002	0.016
CYHEXATIN	0	0	0	0	0	0	0.418	0.418
CYMOXANIL	0	0	0	0	0.143	0	0.117	0.260
CYPERMETHRIN	0.010	0	0.085	0.019	0.020	0	0.029	0.163
CYROMAZINE	0	0	0	0	0	0	0.082	0.082
CYTOKININ	0	0	0	0.061	0.062	0	0.123	0.246
DELTAMETHRIN	0	0	0	0.003	0.005	0.004	0.002	0.014
DEMETON-S-M	0	0	0	0	0.126	0	0.114	0.239
DICHLORVOS	0	0	0	0	0.500	0	0.999	1.499
DICOFOL	0	0.389	0	0	0	0	0.350	0.739
DIFENOCONAZOLE	0	0	0	0	0.751	0	0	0.751
DIMETHOATE	0	0	1.811	0	0.160	0.321	0	2.291
DINOSEB	0	0	0	0	2.597	0	0	2.597
DISULFOTON	0	0	0	0	0.653	0	1.000	1.653
EBUFOS	0	4.056	9.081	0	0	0	0	13.137
ENDOSULFAN	0	0	1.226	0.227	0.264	0.933	0.695	3.345
ETHEPHON	0	0	0	0	0.720	0	0	0.720
ETHYLENEDIBROMDE	0	0	0	0	18.602	25.978	23.339	67.919
FENAMIPHOS	0	6.169	8.098	0	1.400	1.430	1.434	18.530
FENBUTATINOXIDE	0	0	1.100	0	0	0	0	1.100
FENPROPATHRIN	0	0	0.898	0	0	0	0	0.898
FENTIN-ACETATE	0	0	0	0	0.215	0	0	0.215
FENTIN-HYDROXIDE	0	0	0	0	0.350	0	0	0.350
FENVALERATE	0	0	0	0.017	0.035	0	0.021	0.073
FLUAZIFOP-B	0	0	0	0	0.045	0	0	0.045
FLURAZOLE	0	0	0	0	0.012	0	0	0.012
FOSETYL-AL	0	0	9.384	0	0	0	0	9.384
FURALAXYL	0	0	28.000	0	0	0	0	28.000
FURATHIOCARB	0	0	0	0.180	0	0	0	0.180
GIBBERELLIC-ACID	0	0	2.606	0	0.502	0	0	3.108
HYDRAMETHYLNON	0	0	0.273	0	0	0	0	0.273
IMIDACLOPRID	0	0	0	0.007	0	0	0	0.007
IPRODIONE	0	0	0	0	0	0	0.504	0.504
ISAZOPHOS	0	0	0.625	0.208	0.249	0	0	1.081
ISOFENPHOS	0	0	1.500	0.356	0	0	0	1.857
LINDANE	0.059	0	0.122	0.008	0.108	0	0	0.297

Crocodile	Forest	Bananas	Citrus	Corn	Sugar	Tobacco	Tomatoes	Total
MANCOZEB	0	2.000	9.599	0	1.720	0	1.559	14.878
MANEB	0	0	0	0	0.072	0	0	0.072
MERCAPTOTHION	0	1.252	0.352	0	0	0	0	1.604
METALAXYL	0	0	4.988	0	0.200	2.611	0.200	7.999
METALDEHYDE	0	0.611	1.500	0	0	0	0	2.111
METHAMIDOPHOS	0	0	3.017	0	0.195	0	0.585	3.797
METHIDATHION	0	0	1.156	0	0	0	0	1.156
METHIOCARB	0	0.667	0.206	0	0	0	0	0.873
METHOMYL	0	0	0.229	0	0.226	0.225	0.295	0.975
METHYLBROMIDE	0	0	0	0	0	520.857	524.500	1045.35
MEVINPHOS	0	0	0.375	0	0	0.151	0.113	0.638
MONOCROTOPHOS	0	0	0.400	0.240	0	0.240	0.600	1.481
N-DECANOL	0	0	0	0	0	4.302	0	4.302
N-OCTANOL	0	0	0	0	0	2.102	0	2.102
OIL	0	4.172	25.057	0	0	0	0	29.229
OMETHOATE	0	0	2.000	0	0	0	0	2.000
OXADIXYL	0	0	0	0	0.200	0	0.160	0.359
OXAMYL	0	0	0	0	2.286	1.143	0.929	4.358
PACLOBUTRAZOL	0	0	1.000	0	0	0	0	1.000
PARAQUAT	0	0	0	0	0.750	0	0	0.750
PARATHION-E	0	0	3.127	0	0.289	0	0	3.416
PENCYCURON	0	0	0	0	0.125	0	0	0.125
PENDIMETHALIN	0	0	0	0	0	0.452	0	0.452
PERMETHRIN	0	0	0	0.160	0.050	0	0.038	0.248
PHENTHOATE	0	0	0.804	0	0	0	0	0.804
PHORATE	0	0	0	0.420	0	0	0	0.420
PHOXIM	0	0	0	3.000	0	0	0	3.000
PIRIMIPHOS-E	0	3.000	0	0	0	0	0	3.000
PIRIMIPHOS-M	0	0	0	0.150	0	0	0	0.150
PROCHLORAZMG	0	0.337	0	0	0	0	0	0.337
PROCYMIDONE	0	0	2.000	0	0.183	0	0.126	2.309
PROFENOFOS	0	0	1.148	0	0.375	0	0.562	2.085
PROPARGITE	0	0	0	0	0	0	0.620	0.620
PROPINEB	0	0	0	0	1.754	0	1.401	3.155
PROPOXUR	0	0	0	0.500	0	0	0	0.500
PROTEINHYDROLIS.	0	0	0.188	0	0	0	0	0.188
PROTHIOFOS	0	0	2.143	0	0	0	0	2.143
PYRIPROXIFEN	0	0	0.015	0	0	0	0	0.015
QUINALPHOS	0	0	0	0.415	0	0	0	0.415
QUINOMETHIONATE	0	0	0.474	0	0	0	0.186	0.660
QUINTOZENE(PCNB)	0	0	0	0	29.886	0	0	29.886
SODIUMFLUOSILIC.	0	0	0	0.500	0	0.744	2.000	3.244
SUGAR	0	0	5.000	0	0	0	0	5.000
SULPHUR	0	0	0	0	0	0	18.167	18.167
TARTAREMETIC	0	0	4.275	0	0	0	0	4.275
TEBUCONAZOLE	2.400	0	0	0	0	0	0	2.400
TEFLUBENZURON	0	0	0.239	0	0	0	0	0.239
TERBUFOS	0	0	17.423	0.420	0.350	0	0	18.193
TETRADIFON	0	0	0.403	0	0	0	0	0.403
THIODICARB	0	0	0	0.124	0.094	0	0	0.218
THIOMETON	0	0	0	0	0.140	0	0	0.140
THIOPHANATE	0	0	3.043	0	0	0	0	3.043
THIRAM	0	0	0	0.018	0.115	72.000	0	72.133
TRALOMETHRIN	0	0	0	0.011	0	0	0	0.011
TRIADIMEFON	0	0.042	0	0.008	0.129	0	0	0.178
TRIADIMENOL	0	0	0	0	0	0.451	0	0.451
TRIAZOPHOS	0	0.340	1.132	0	0	0	0	1.473
TRICHLORFON	0	0	0.047	0.168	0	0	0.572	0.787
TRIFLUMURON	0	0	0.382	0	0	0	0	0.382
ZINEB	0	0	0	0	0	18.000	0.400	18.400

Appendix E: Pesticide usage for the Letaba River.

Letaba	Forest	Bananas	Citrus	Mangoes	Tomatoes	Total
ABAMECTIN	0	0	0	0	0.011	0.011
ACETOCHLOR	1.801	0	0	0	0	1.801
ALDICARB	0	5.994	8.239	0	3.008	17.241
ALPHACYPERMETHRIN	0.004	0	0	0	0.007	0.011
AMETRYN	0	3.216	0	0	0	3.216
AMITRAZ	0	0	1.200	0	0	1.200
ANILAZINE	0	0	0	0	1.504	1.504
BACILLUS-THUR.	0	0	0.251	0	0	0.251
BENOMYL	0	0.583	2.253	0.498	0.175	3.508
BIFENTHRIN	0	0	0	0	0.041	0.041
BROMACIL	0	0	4.000	0	0	4.000
BROMOPROPYLATE	0	0.048	0.100	0.072	0	0.220
BUPIRIMATE	0	0	0	0.356	0	0.356
BUPROFEZIN	0	0	0.751	0	0	0.751
CALCIUM-ARSENATE	0	0	3.421	0	0	3.421
CAPTAN	0	0	0	0	1.000	1.000
CARBARYL	0	0.389	1.000	0	0	1.389
CARBENDAZIM	0	0	2.503	0.075	0	2.578
CARBOSULFAN	4.127	0	0	0	0	4.127
CHLORDANE	2.635	0	1.958	0	0	4.593
CHLOROTHALONIL	0	0	0	0	1.000	1.000
CHLORPYRIFOS	0.475	0.360	0.943	0	0.480	2.258
COPPER-HYDROXIDE	0	0	8.400	0	1.540	9.940
COPPER-OXYCHLORIDE	0	0	10.196	8.977	2.533	21.706
COPPER-SULPHATE	0	0	0	2.546	1.750	4.296
CUPRAMMONIUMCOMPLEX	0	0	0	0	3.250	3.250
CYCLOXYDIM	0	0	0.167	0	0.211	0.377
CYFLUTHRIN	0	0	0	0	0.009	0.009
CYHALOTHRIN-L	0.003	0	0	0	0.002	0.006
CYHEXATIN	0	0	0	0	0.418	0.418
CYMOXANIL	0	0	0	0	0.117	0.117
CYPERMETHRIN	0.010	0	0.085	0	0.029	0.124
CYROMAZINE	0	0	0	0	0.082	0.082
CYTOKININ	0	0	0	0	0.123	0.123
DELTAMETHRIN	0	0	0	0	0.002	0.002
DEMETON-S-M	0	0	0	0	0.114	0.114
DICHLORVOS	0	0	0	0	0.999	0.999
DICOFOL	0	0.389	0	0	0.350	0.739
DIMETHOATE	0	0	1.811	0	0	1.811
DIPHENAMID	0	0	0	0	4.968	4.968
DISULFOTON	0	0	0	0	1.000	1.000
DIURON	0	3.167	3.139	2.000	0	8.305
EBUFOS	0	4.056	9.081	0	0	13.137
ENDOSULFAN	0	0	1.226	0	0.695	1.921
ETHYLENEDIBROMIDE	0	0	0	0	23.339	23.339
FENAMIPHOS	0	6.169	8.098	8.500	1.434	24.201
FENBUTATINOXIDE	0	0	1.100	0	0	1.100
FENPROPATHRIN	0	0	0.898	0	0	0.898
FENTHION	0	0	0	1.886	0	1.886
FENVALERATE	0	0	0	0.214	0.021	0.236
FLUAZIFOP-B	0.375	0.381	0.380	0	0	1.135
FLUSILAZOLE	0	0	0	0.150	0	0.150
FOSETYL-AL	0	0	9.384	0	0	9.384
FURALAXYL	0	0	28.000	0	0	28.000
GIBBERELLIC-ACID	0	0	2.606	0	0	2.606
GLYPHOSATE	1.440	0.564	0.556	1.333	2.154	6.046
HYDRAMETHYLNON	0	0	0.273	0	0	0.273
IMAZAPYR	2.500	0	0	0	0	2.500

Letaba	Forest	Bananas	Citrus	Mangoes	Tomatoes	Total
IPRODIONE	0	0	0	0	0.504	0.504
ISAZOPHOS	0	0	0.625	0	0	0.625
ISOFENPHOS	0	0	1.500	0	0	1.500
LINDANE	0.059	0	0.122	0	0	0.180
MANCOZEB	0	2.000	9.599	6.000	1.559	19.158
MERCAPTOTHION	0	1.252	0.352	0.075	0	1.679
METALAXYL	0	0	4.988	0	0.200	5.188
METALDEHYDE	0	0.611	1.500	0	0	2.111
METHAMIDOPHOS	0	0	3.017	0	0.585	3.602
METHIDATHION	0	0	1.156	0	0	1.156
METHIOCARB	0	0.667	0.206	0	0	0.873
METHOMYL	0	0	0.229	0	0.295	0.525
METHYLBROMIDE	0	0	0	0	524.500	524.500
METOLACHLOR	1.921	0	0	0	0	1.921
METRIBUZIN	0	0	0	0	0.678	0.678
MEVINPHOS	0	0	0.375	0	0.113	0.488
MONOCROTOPHOS	0	0	0.400	0	0.600	1.001
OIL	0	4.172	25.057	0	0	29.229
OMETHOATE	0	0	2.000	0	0	2.000
OXADIXYL	0	0	0	0	0.160	0.160
OXAMYL	0	0	0	0	0.929	0.929
OXYFLUORFEN	0.721	0	0.700	0	0	1.421
PACLOBUTRAZOL	0	0	1.000	0	0	1.000
PARAQUAT	0.500	0.400	0.602	0.600	0.600	2.702
PARATHION-E	0	0	3.127	1.625	0	4.752
PERMETHRIN	0	0	0	0	0.038	0.038
PHENTHOATE	0	0	0.804	2.500	0	3.304
PIRIMIPHOS-E	0	3.000	0	0	0	3.000
PROCHLORAZMG	0	0.337	0	0	0	0.337
PROCYMIDONE	0	0	2.000	0	0.126	2.126
PROFENOFOS	0	0	1.148	0	0.562	1.711
PROPARGITE	0	0	0	0	0.620	0.620
PROPICONAZOLE	0	0	0	0.200	0	0.200
PROPINEB	0	0	0	0	1.401	1.401
PROTEINHYDROLISATE	0	0	0.188	0.188	0	0.375
PROTHIOFOS	0	0	2.143	1.552	0	3.695
PYRAZOPHOS	0	0	0	0.443	0	0.443
PYRIPROXIFEN	0	0	0.015	0	0	0.015
QUINOMETHIONATE	0	0	0.474	0	0.186	0.660
SIMAZINE	0	0	2.513	0	0	2.513
SODIUMFLUOSILICATE	0	0	0	0	2.000	2.000
SUGAR	0	0	5.000	0	0	5.000
SULPHUR	0	0	0	23.302	18.167	41.468
TARTAREMETIC	0	0	4.275	0	0	4.275
TEBUCONAZOLE	2.400	0	0	0	0	2.400
TEFLUBENZURON	0	0	0.239	0	0	0.239
TERBUFOS	0	0	17.423	0	0	17.423
TETRADIFON	0	0	0.403	0	0	0.403
THIOPHANATE	0	0	3.043	0	0	3.043
TRIADIMEFON	0	0.042	0	0.333	0	0.375
TRIADIMENOL	0	0	0	0.189	0	0.189
TRIAZOPHOS	0	0.340	1.132	0	0	1.473
TRICHLORFON	0	0	0.047	0.048	0.572	0.667
TRICLOPYR	9.634	0	0	0	0	9.634
TRIFLUMURON	0	0	0.382	0	0	0.382
TRIFLURALIN	0	0	0	0	0.727	0.727
TRIFORINE	0	0	0	0.600	0	0.600
ZINEB	0	0	0	0	0.400	0.400

Appendix E: Pesticide usage for the Luvuvhu River.

Luvuvhu	Forest	Bananas	Corn	Mangoes	Tobacco	Total
2,4-DAMINE	0	0	0.270	0	0	0.270
2,4-DESTER	0	0	0.375	0	0	0.375
ACEPHATE	0	0	0	0	0.764	0.764
ACETOCHLOR	1.801	0	0.877	0	0	2.678
ALACHLOR	0	0	1.757	0	0	1.757
ALDICARB	0	5.994	1.492	0	3.000	10.487
ALPHACYPERMETHRIN	0.004	0	0.007	0	0.005	0.016
AMETRYN	0	3.216	0	0	0	3.216
ATRAZINE	0	0	1.125	0	0	1.125
BENFURACARB	0	0	0.202	0	0	0.202
BENOMYL	0	0.583	0	0.498	4.000	5.081
BENTAZONE	0	0	1.670	0	0	1.670
BROMOPROPYLATE	0	0.048	0	0.072	0	0.120
BROMOXYNIL	0	0	0.244	0	0	0.244
BUPIRIMATE	0	0	0	0.356	0	0.356
BUTRALIN	0	0	0	0	0.718	0.718
BUTYLATE	0	0	2.699	0	0	2.699
CAPTAN	0	0	0.019	0	2.611	2.630
CARBARYL	0	0.389	0.100	0	0.972	1.461
CARBENDAZIM	0	0	0	0.075	0	0.075
CARBOFURAN	0	0	1.660	0	1.989	3.649
CARBOSULFAN	4.127	0	2.009	0	0	6.137
CHLORDANE	2.635	0	0	0	0	2.635
CHLOROPICRIN	0	0	0	0	47.791	47.791
CHLORPYRIFOS	0.475	0.360	0.223	0	0.864	1.921
CHLORTHAL	0	0	0	0	0.719	0.719
CLOMAZONE	0	0	0	0	0.958	0.958
COPPER-OXYCHLORIDE	0	0	0	8.977	28.021	36.997
COPPER-SULPHATE	0	0	0	2.546	0	2.546
CYANAZINE	0	0	0.949	0	0	0.949
CYCLOATE	0	0	2.161	0	0	2.161
CYCLOXYDIM	0	0	0	0	0.182	0.182
CYFLUTHRIN	0	0	0.006	0	0	0.006
CYHALOTHRIN-L	0.003	0	0.004	0	0.003	0.010
CYPERMETHRIN	0.010	0	0.019	0	0	0.029
CYTOKININ	0	0	0.061	0	0	0.061
DELTAMETHRIN	0	0	0.003	0	0.004	0.007
DICAMBA	0	0	0.241	0	0	0.241
DICOFOL	0	0.389	0	0	0	0.389
DIMETHOATE	0	0	0	0	0.321	0.321
DIPHENAMID	0	0	0	0	2.010	2.010
DIURON	0	3.167	0	2.000	0	5.167
EBUFOS	0	4.056	0	0	0	4.056
ENDOSULFAN	0	0	0.227	0	0.933	1.160
EPTC	0	0	2.160	0	0	2.160
ETHYLENEDIBROMIDE	0	0	0	0	25.978	25.978
FENAMIPHOS	0	6.169	0	8.500	1.430	16.098
FENTHION	0	0	0	1.886	0	1.886
FENVALERATE	0	0	0.017	0.214	0	0.232
FLUAZIFOP-B	0.375	0.381	0	0	0	0.756
FLUSILAZOLE	0	0	0	0.150	0	0.150
FURATHIOCARB	0	0	0.180	0	0	0.180
GLYPHOSATE	1.440	0.564	0.540	1.333	0	3.877
IMAZAPYR	2.500	0	0	0	0	2.500
IMIDACLOPRID	0	0	0.007	0	0	0.007
ISAZOPHOS	0	0	0.208	0	0	0.208

Luvuvhu	Forest	Bananas	Corn	Mangoes	Tobacco	Total
ISOFENPHOS	0	0	0.356	0	0	0.356
LINDANE	0.059	0	0.008	0	0	0.067
MANCOZEB	0	2.000	0	6.000	0	8.000
MCPA	0	0	1.000	0	0	1.000
MERCAPTOTHION	0	1.252	0	0.075	0	1.327
METALAXYL	0	0	0	0	2.611	2.611
METALDEHYDE	0	0.611	0	0	0	0.611
METAZACHLOR	0	0	0.611	0	0.593	1.204
METHIOCARB	0	0.667	0	0	0	0.667
METHOMYL	0	0	0	0	0.225	0.225
METHYLBROMIDE	0	0	0	0	520.857	520.857
METOLACHLOR	1.921	0	0.798	0	1.396	4.116
MEVINPHOS	0	0	0	0	0.151	0.151
MONOCROTOPHOS	0	0	0.240	0	0.240	0.480
N-DECANOL	0	0	0	0	4.302	4.302
NICOSULFURON	0	0	0.450	0	0	0.450
N-OCTANOL	0	0	0	0	2.102	2.102
OIL	0	4.172	0	0	0	4.172
OXAMYL	0	0	0	0	1.143	1.143
OXYFLUORFEN	0.721	0	0	0	0	0.721
PARAQUAT	0.500	0.400	0.300	0.600	0	1.800
PARATHION-E	0	0	0	1.625	0	1.625
PEBULATE	0	0	0	0	5.042	5.042
PENDIMETHALIN	0	0	0	0	0.452	0.452
PENDIMETHALIN	0	0	0	0	1.002	1.002
PERMETHRIN	0	0	0.160	0	0	0.160
PHENTHOATE	0	0	0	2.500	0	2.500
PHORATE	0	0	0.420	0	0	0.420
PHOXIM	0	0	3.000	0	0	3.000
PIRIMIPHOS-E	0	3.000	0	0	0	3.000
PIRIMIPHOS-M	0	0	0.150	0	0	0.150
PRIMISULFURON	0	0	0.010	0	0	0.010
PROCHLORAZMG	0	0.337	0	0	0	0.337
PROPAZINE	0	0	1.010	0	0	1.010
PROPICONAZOLE	0	0	0	0.200	0	0.200
PROPOXUR	0	0	0.500	0	0	0.500
PROTEINHYDROLISATE	0	0	0	0.188	0	0.188
PROTHIOFOS	0	0	0	1.552	0	1.552
PYRAZOPHOS	0	0	0	0.443	0	0.443
QUINALPHOS	0	0	0.415	0	0	0.415
SIMAZINE	0	0	0.825	0	0	0.825
SODIUMFLUOSILICATE	0	0	0.500	0	0.744	1.244
SULCITRIONE	0	0	0.149	0	0	0.149
SULPHUR	0	0	0	23.302	0	23.302
TEBUCONAZOLE	2.400	0	0	0	0	2.400
TERBUFOS	0	0	0.420	0	0	0.420
TERBUTHYLAZINE	0	0	0.877	0	0	0.877
THIODICARB	0	0	0.124	0	0	0.124
THIRAM	0	0	0.018	0	72.000	72.018
TRALOMETHRIN	0	0	0.011	0	0	0.011
TRIADIMEFON	0	0.042	0.008	0.333	0	0.383
TRIADIMENOL	0	0	0	0.189	0.451	0.640
TRIAZOPHOS	0	0.340	0	0	0	0.340
TRICHLORFON	0	0	0.168	0.048	0	0.215
TRICLOPYR	9.634	0	0	0	0	9.634
TRIFORINE	0	0	0	0.600	0	0.600
ZINEB	0	0	0	0	18.000	18.000

Appendix E: Pesticide usage for the Olifants River.

Olifants	Forest	Bananas	Citrus	Corn	Tobacco	Tomatoes	Total
2,4-DAMINE	0	0	0	0.270	0	0	0.270
2,4-DESTER	0	0	0	0.375	0	0	0.375
ABAMECTIN	0	0	0	0	0	0.011	0.011
ACEPHATE	0	0	0	0	0.764	0	0.764
ACETOCHLOR	1.801	0	0	0.877	0	0	2.678
ALACHLOR	0	0	0	1.757	0	0	1.757
ALDICARB	0	5.994	8.239	1.492	3.000	3.008	21.734
ALPHACYPERMETHRIN	0.004	0	0	0.007	0.005	0.007	0.023
AMETRYN	0	3.216	0	0	0	0	3.216
AMITRAZ	0	0	1.200	0	0	0	1.200
ANILAZINE	0	0	0	0	0	1.504	1.504
ATRAZINE	0	0	0	1.125	0	0	1.125
BACILLUS-THUR.	0	0	0.251	0	0	0	0.251
BENFURACARB	0	0	0	0.202	0	0	0.202
BENOMYL	0	0.583	2.253	0	4.000	0.175	7.011
BENTAZONE	0	0	0	1.670	0	0	1.670
BIFENTHRIN	0	0	0	0	0	0.041	0.041
BROMACIL	0	0	4.000	0	0	0	4.000
BROMOPROPYLATE	0	0.048	0.100	0	0	0	0.147
BROMOXYNIL	0	0	0	0.244	0	0	0.244
BUPROFEZIN	0	0	0.751	0	0	0	0.751
BUTRALIN	0	0	0	0	0.718	0	0.718
BUTYLATE	0	0	0	2.699	0	0	2.699
CALCIUM-ARSENATE	0	0	3.421	0	0	0	3.421
CAPTAN	0	0	0	0.019	2.611	1.000	3.630
CARBARYL	0	0.389	1.000	0.100	0.972	0	2.461
CARBENDAZIM	0	0	2.503	0	0	0	2.503
CARBOFURAN	0	0	0	1.660	1.989	0	3.649
CARBOSULFAN	4.127	0	0	2.009	0	0	6.137
CHLORDANE	2.635	0	1.958	0	0	0	4.593
CHLOROPICRIN	0	0	0	0	47.791	0	47.791
CHLOROTHALONIL	0	0	0	0	0	1.000	1.000
CHLORPYRIFOS	0.475	0.360	0.943	0.223	0.864	0.480	3.344
CHLORTHAL	0	0	0	0	0.719	0	0.719
CLOMAZONE	0	0	0	0	0.958	0	0.958
COPPER-HYDROXIDE	0	0	8.400	0	0	1.540	9.940
COPPER-OXYCHLOR.	0	0	10.196	0	28.021	2.533	40.750
COPPER-SULPHATE	0	0	0	0	0	1.750	1.750
CUPRAMMONIUMCMP.	0	0	0	0	0	3.250	3.250
CYANAZINE	0	0	0	0.949	0	0	0.949
CYCLOATE	0	0	0	2.161	0	0	2.161
CYCLOXYDIM	0	0	0.167	0	0.182	0.211	0.559
CYFLUTHRIN	0	0	0	0.006	0	0.009	0.016
CYHALOTHRIN-L	0.003	0	0	0.004	0.003	0.002	0.013
CYHEXATIN	0	0	0	0	0	0.418	0.418
CYMOXANIL	0	0	0	0	0	0.117	0.117
CYPERMETHRIN	0.010	0	0.085	0.019	0	0.029	0.143
CYROMAZINE	0	0	0	0	0	0.082	0.082
CYTOKININ	0	0	0	0.061	0	0.123	0.185
DELTAMETHRIN	0	0	0	0.003	0.004	0.002	0.009

Olifants	Forest	Bananas	Citrus	Corn	Tobacco	Tomatoes	Total
DEMETON-S-M	0	0	0	0	0	0.114	0.114
DICAMBA	0	0	0	0.241	0	0	0.241
DICHLORVOS	0	0	0	0	0	0.999	0.999
DICOFOL	0	0.389	0	0	0	0.350	0.739
DIMETHOATE	0	0	1.811	0	0.321	0	2.132
DIPHENAMID	0	0	0	0	2.010	4.968	6.978
DISULFOTON	0	0	0	0	0	1.000	1.000
DIURON	0	3.167	3.139	0	0	0	6.305
EBUFOS	0	4.056	9.081	0	0	0	13.137
ENDOSULFAN	0	0	1.226	0.227	0.933	0.695	3.081
EPTC	0	0	0	2.160	0	0	2.160
ETHYLENEDIBROMIDE	0	0	0	0	25.978	23.339	49.317
FENAMIPHOS	0	6.169	8.098	0	1.430	1.434	17.131
FENBUTATINOXIDE	0	0	1.100	0	0	0	1.100
FENPROPATHRIN	0	0	0.898	0	0	0	0.898
FENVALERATE	0	0	0	0.017	0	0.021	0.039
FLUAZIFOP-B	0.375	0.381	0.380	0	0	0	1.135
FOSETYL-AL	0	0	9.384	0	0	0	9.384
FURALAXYL	0	0	28.000	0	0	0	28.000
FURATHIOCARB	0	0	0	0.180	0	0	0.180
GIBBERELLIC-ACID	0	0	2.606	0	0	0	2.606
GLYPHOSATE	1.440	0.564	0.556	0.540	0	2.154	5.253
HYDRAMETHYLNON	0	0	0.273	0	0	0	0.273
IMAZAPYR	2.500	0	0	0	0	0	2.500
IMIDACLOPRID	0	0	0	0.007	0	0	0.007
IPRODIONE	0	0	0	0	0	0.504	0.504
ISAZOPHOS	0	0	0.625	0.208	0	0	0.832
ISOFENPHOS	0	0	1.500	0.356	0	0	1.857
LINDANE	0.059	0	0.122	0.008	0	0	0.188
MANCOZEB	0	2.000	9.599	0	0	1.559	13.158
MCPA	0	0	0	1.000	0	0	1.000
MERCAPTOTHION	0	1.252	0.352	0	0	0	1.604
METALAXYL	0	0	4.988	0	2.611	0.200	7.800
METALDEHYDE	0	0.611	1.500	0	0	0	2.111
METAZACHLOR	0	0	0	0.611	0.593	0	1.204
METHAMIDOPHOS	0	0	3.017	0	0	0.585	3.602
METHIDATHION	0	0	1.156	0	0	0	1.156
METHIOCARB	0	0.667	0.206	0	0	0	0.873
METHOMYL	0	0	0.229	0	0.225	0.295	0.750
METHYLBROMIDE	0	0	0	0	520.857	524.500	1045.357
METOLACHLOR	1.921	0	0	0.798	1.396	0	4.116
METRIBUZIN	0	0	0	0	0	0.678	0.678
MEVINPHOS	0	0	0.375	0	0.151	0.113	0.638
MONOCROTOPHOS	0	0	0.400	0.240	0.240	0.600	1.481
N-DECANOL	0	0	0	0	4.302	0	4.302
NICOSULFURON	0	0	0	0.450	0	0	0.450
N-OCTANOL	0	0	0	0	2.102	0	2.102
OIL	0	4.172	25.057	0	0	0	29.229
OMETHOATE	0	0	2.000	0	0	0	2.000
OXADIXYL	0	0	0	0	0	0.160	0.160

Olifants	Forest	Bananas	Citrus	Corn	Tobacco	Tomatoes	Total
OXAMYL	0	0	0	0	1.143	0.929	2.072
OXYFLUORFEN	0.721	0	0.700	0	0	0	1.421
PACLOBUTRAZOL	0	0	1.000	0	0	0	1.000
PARAQUAT	0.500	0.400	0.602	0.300	0	0.600	2.402
PARATHION-E	0	0	3.127	0	0	0	3.127
PEBULATE	0	0	0	0	5.042	0	5.042
PENDIMETHALIN	0	0	0	0	1.002	0	1.002
PENDIMETHALIN	0	0	0	0	0.452	0	0.452
PERMETHRIN	0	0	0	0.160	0	0.038	0.198
PHENTHOATE	0	0	0.804	0	0	0	0.804
PHORATE	0	0	0	0.420	0	0	0.420
PHOXIM	0	0	0	3.000	0	0	3.000
PIRIMIPHOS-E	0	3.000	0	0	0	0	3.000
PIRIMIPHOS-M	0	0	0	0.150	0	0	0.150
PRIMISULFURON	0	0	0	0.010	0	0	0.010
PROCHLORAZMG	0	0.337	0	0	0	0	0.337
PROCYMIDONE	0	0	2.000	0	0	0.126	2.126
PROFENOFOS	0	0	1.148	0	0	0.562	1.711
PROPARGITE	0	0	0	0	0	0.620	0.620
PROPAZINE	0	0	0	1.010	0	0	1.010
PROPINEB	0	0	0	0	0	1.401	1.401
PROPOXUR	0	0	0	0.500	0	0	0.500
PROTEINHYDROLISATE	0	0	0.188	0	0	0	0.188
PROTHIOFOS	0	0	2.143	0	0	0	2.143
PYRIPROXIFEN	0	0	0.015	0	0	0	0.015
QUINALPHOS	0	0	0	0.415	0	0	0.415
QUINOMETHIONATE	0	0	0.474	0	0	0.186	0.660
SIMAZINE	0	0	2.513	0.825	0	0	3.338
SODIUMFLUOSILICATE	0	0	0	0.500	0.744	2.000	3.244
SUGAR	0	0	5.000	0	0	0	5.000
SULCITRIONE	0	0	0	0.149	0	0	0.149
SULPHUR	0	0	0	0	0	18.167	18.167
TARTAREMETIC	0	0	4.275	0	0	0	4.275
TEBUCONAZOLE	2.400	0	0	0	0	0	2.400
TEFLUBENZURON	0	0	0.239	0	0	0	0.239
TERBUFOS	0	0	17.423	0.420	0	0	17.843
TERBUTHYLAZINE	0	0	0	0.877	0	0	0.877
TETRADIFON	0	0	0.403	0	0	0	0.403
THIODICARB	0	0	0	0.124	0	0	0.124
THIOPHANATE	0	0	3.043	0	0	0	3.043
THIRAM	0	0	0	0.018	72.000	0	72.018
TRALOMETHRIN	0	0	0	0.011	0	0	0.011
TRIADIMEFON	0	0.042	0	0.008	0	0	0.049
TRIADIMENOL	0	0	0	0	0.451	0	0.451
TRIAZOPHOS	0	0.340	1.132	0	0	0	1.473
TRICHLORFON	0	0	0.047	0.168	0	0.572	0.787
TRICLOPYR	9.634	0	0	0	0	0	9.634
TRIFLUMURON	0	0	0.382	0	0	0	0.382
TRIFLURALIN	0	0	0	0	0	0.727	0.727
ZINEB	0	0	0	0	18.000	0.400	18.400

Appendix E: **Pesticide usage for the Sabie River.**

Sabie	Forest	Avocados	Bananas	Citrus	Total
ACETOCHLOR	1.801	0	0	0	1.801
ALDICARB	0	0	5.994	8.239	14.234
ALPHACYPERMETHRIN	0.004	0	0	0	0.004
AMETRYN	0	0	3.216	0	3.216
AMITRAZ	0	0	0	1.200	1.200
BACILLUS-THUR.	0	0	0	0.251	0.251
BENOMYL	0	1.250	0.583	2.253	4.086
BROMACIL	0	0	0	4.000	4.000
BROMOPROPYLATE	0	0	0.048	0.100	0.147
BUPROFEZIN	0	0.227	0	0.751	0.977
CALCIUM-ARSENATE	0	0	0	3.421	3.421
CARBARYL	0	0	0.389	1.000	1.389
CARBENDAZIM	0	0	0	2.503	2.503
CARBOSULFAN	4.127	0	0	0	4.127
CHLORDANE	2.635	0	0	1.958	4.593
CHLORPYRIFOS	0.475	0	0.360	0.943	1.778
COPPER-HYDROXIDE	0	0	0	8.400	8.400
COPPER-OXYCHLORIDE	0	12.762	0	10.196	22.958
CYCLOXYDIM	0	0	0	0.167	0.167
CYHALOTHRIN-L	0.003	0	0	0	0.003
CYPERMETHRIN	0.010	0	0	0.085	0.095
DICOFOL	0	0	0.389	0	0.389
DIMETHOATE	0	0	0	1.811	1.811
DIURON	0	3.240	3.167	3.139	9.545
EBUFOS	0	0	4.056	9.081	13.137
ENDOSULFAN	0	0	0	1.226	1.226
FENAMIPHOS	0	0	6.169	8.098	14.267
FENBUTATINOXIDE	0	0	0	1.100	1.100
FENPROPATHRIN	0	0	0	0.898	0.898
FLUAZIFOP-B	0.375	0.353	0.381	0.380	1.488
FOSETYL-AL	0	8.693	0	9.384	18.077
FURALAXYL	0	0	0	28.000	28.000
GIBBERELLIC-ACID	0	0	0	2.606	2.606
GLYPHOSATE	1.440	0.765	0.564	0.556	3.324
HYDRAMETHYLNON	0	0	0	0.273	0.273
IMAZAPYR	2.500	0	0	0	2.500
ISAZOPHOS	0	0	0	0.625	0.625
ISOFENPHOS	0	0	0	1.500	1.500
LINDANE	0.059	0	0	0.122	0.180
MANCOZEB	0	0	2.000	9.599	11.599
MERCAPTOTHION	0	3.771	1.252	0.352	5.375
METALAXYL	0	36.000	0	4.988	40.988
METALDEHYDE	0	0	0.611	1.500	2.111
METHAMIDOPHOS	0	0	0	3.017	3.017
METHIDATHION	0	0	0	1.156	1.156
METHIOCARB	0	0	0.667	0.206	0.873
METHOMYL	0	0	0	0.229	0.229
METOLACHLOR	1.921	0	0	0	1.921

Sabie	Forest	Avocados	Bananas	Citrus	Total
MEVINPHOS	0	0	0	0.375	0.375
MONOCROTOPHOS	0	0	0	0.400	0.400
OIL	0	0	4.172	25.057	29.229
OMETHOATE	0	0	0	2.000	2.000
OXYFLUORFEN	0.721	0	0	0.700	1.421
PACLOBUTRAZOL	0	1.000	0	1.000	2.000
PARAQUAT	0.500	0.400	0.400	0.602	1.903
PARATHION-E	0	0	0	3.127	3.127
PHENTHOATE	0	0	0	0.804	0.804
PIRIMIPHOS-E	0	0	3.000	0	3.000
PROCHLORAZ	0	0.370	0	0	0.370
PROCHLORAZMG	0	0	0.337	0	0.337
PROCYMIDONE	0	0	0	2.000	2.000
PROFENOFOS	0	0	0	1.148	1.148
PROTEINHYDROLISATE	0	0	0	0.188	0.188
PROTHIOFOS	0	0	0	2.143	2.143
PYRIPROXIFEN	0	0	0	0.015	0.015
QUINOMETHIONATE	0	0	0	0.474	0.474
SIMAZINE	0	0	0	2.513	2.513
SUGAR	0	0	0	5.000	5.000
SULPHUR	0	6.000	0	0	6.000
TARTAREMETIC	0	0	0	4.275	4.275
TEBUCONAZOLE	2.400	0	0	0	2.400
TEFLUBENZURON	0	0.200	0	0.239	0.439
TERBUFOS	0	0	0	17.423	17.423
TETRADIFON	0	0	0	0.403	0.403
THIABENDAZOLE	0	0.089	0	0	0.089
THIOPHANATE	0	0	0	3.043	3.043
TRIADIMEFON	0	0	0.042	0	0.042
TRIAZOPHOS	0	0	0.340	1.132	1.473
TRICHLORFON	0	0	0	0.047	0.047
TRICLOPYR	9.634	0	0	0	9.634
TRIFLUMURON	0	0	0	0.382	0.382

Appendix F

Health Risk Assessment

Appendix F1: Risk assessment for exposure to Dieldrin

Exposure	Geometric means 4 µg/kg		Maximum values 120 µg/kg	
	Cancer risks	Hazard quotient	Cancer risks	Hazard quotient
Weekly - 50 g	3 in 10^{6}	0.0008	8 in $10^{5\#\#}$	0.2
Daily - 50 g	2 in $10^{5\#\#}$	0.05	6 in $10^{4\#\#}$	2
Weekly - 150g	8 in $10^{6\#\#}$	0.02	3 in $10^{4\#\#}$	0.7
Daily - 150g	6 in $10^{5\#\#}$	0.2	2 in $10^{3\#\#}$	5

$^{\#\#}$ refers to risks being higher than recommended or accepted by the US-EPA

Appendix F2: Risk assessment for exposure to Lindane

Exposure	Geometric means 21.3 µg/kg		Maximum values 270 µg/kg	
	Cancer risks	Hazard quotient	Cancer risks	Hazard quotient
Weekly - 50 g	1 in 10^{6}	0.007	2 in $10^{5\#\#}$	0.09
Daily - 50 g	8 in $10^{6\#\#}$	0.05	1 in $10^{4\#\#}$	0.6
Weekly -150g	4 in $10^{6\#\#}$	0.02	5 in $10^{5\#\#}$	0.3
Daily - 150g	2 in $10^{5\#\#}$	0.1	3 in $10^{4\#\#}$	$2^{\#\#}$

$^{\#\#}$ refers to risks or hazard quotient higher than recommended or accepted by the US-EPA

Appendix F3: Risk assessment for exposure to Atrazine

Exposure	Geometric means 0.5 μg/kg		Maximum values 0.5 μg/kg	
	Cancer risks	Hazard quotient	Cancer risk	Hazard quotient
Weekly - 50 g	5 in 10^9	0.00001	Same as for geometric means	
Daily - 50 g	3 in 10^8	0.00007		
Weekly - 150g	1 in 10^8	0.00003		
Daily - 150g	1 in 10^7	0.0002		

Appendix F4: Risk assessment for exposure to DDT

Exposure	Geometric means 5 μg/kg		Maximum values 5 μg/kg	
	Cancer risks	Hazard quotient	Cancer risk	Hazard quotient
Weekly - 50 g	7 in 10^8	0.001	Same as for geometric means	
Daily - 50 g	5 in 10^7	0.007		
Weekly -150g	2 in 10^7	0.003		
Daily - 150g	1 in 10^6	0.02		

Appendix F5: Risk assessment for exposure to DDE

Exposure	Geometric means 14.7 μg/kg		Maximum values 106 μg/kg	
	Cancer risks	Hazard quotient	Cancer risk	Hazard quotient
Weekly - 50 g	2 in 10^7	No data	2 in 10^{6}##	
Daily - 50 g	1 in 10^6		1 in 10^{5}##	
Weekly -150g	7 in 10^7		5 in 10^{6}##	
Daily - 150g	4 in 10^{6}##		3 in 10^{5}##	

refers to risk higher than recommended or accepted by US-EPA

Appendix F6: Risk assessment for exposure to Endosulfan

Exposure	Geometric means 76.5 μg/kg		Maximum values 1073 μg/kg	
	Cancer risks	Hazard quotient	Cancer risk	Hazard quotient
Weekly - 50 g	Not applicable	0.04		0.5
Daily - 50 g		0.3		4.0##
Weekly -150g		0.1		2.0##
Daily - 150g		0.8		10##

refers to hazard quotient higher than recommended or accepted by US-EPA