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The Zambezi Society and The Biodiversity Foundation for Africa are working as partners within the African Wildlife Foundation's Four Corners TBNRM project. The Biodiversity Foundation for Africa is responsible for acquiring technical information on the biodiversity of the project area. The Zambezi Society will be interpreting this information into user-friendly formats for stakeholders in the Four Corners area, and then disseminating it to these stakeholders.

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THE ZAMBEZI SOCIETY was established in 1982. Its goals include the conservation of biological diversity and wilderness in the Zambezi Basin through the application of sustainable, scientifically sound natural resource management strategies. Through its skills and experience in advocacy and information dissemination, it interprets biodiversity information collected by specialists like the Biodiversity Foundation for Africa and uses it to provide a technically sound basis for the implementation of conservation projects within the Zambezi Basin.

THE PARTNERSHIP between these two agencies was formed in 1996 as a result of mutual recognition of their complementarity. They have previously worked together on several major projects, including the biodiversity component of IUCN's Zambezi Basin Wetland project and the evaluation of biodiversity in Tete province described in detail in the first Four Corners TBNRM Biodiversity Information Package.

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CHAPTER 12. ACQUATIC INVERTEBRATES OF THE FOUR CORNERS AREA

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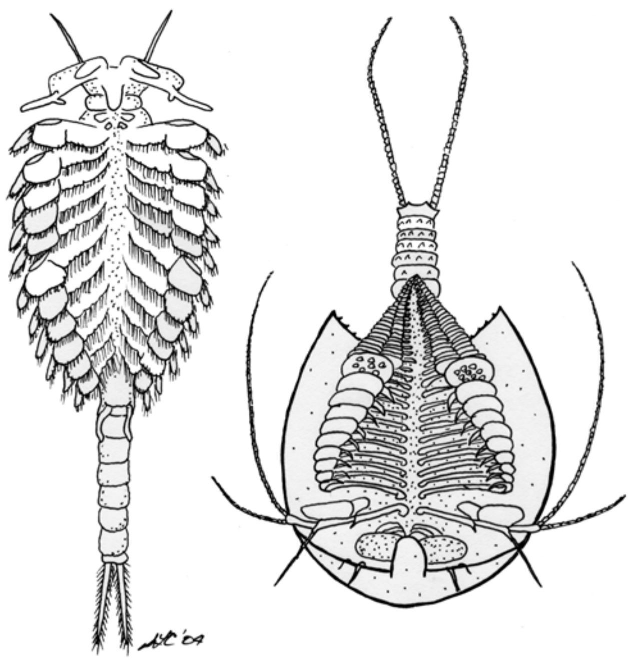

An *Anostacan* (left)
A *Notostracan* (right)

CHAPTER 12. AQUATIC INVERTEBRATES OF THE FOUR CORNERS AREA

Brian Marshall

12.1 INTRODUCTION

Invertebrates constitute the great majority of animal species and are placed in 32-48 phyla, about 15 of which are represented in freshwaters (Edmondson 1959, Durand & Lèvêque 1980, 1981). Some invertebrate phyla are very large, such as the Mollusca with 90,000 species, or the Insecta with 950,000 (Brusca & Brusca 1990, Hammond 1992). Most authorities agree that in some phyla the number of undescribed species may greatly exceed the number of described ones. It has been estimated that there may be around 1.5 million described animal species and perhaps 10-30 million undescribed ones (Hammond 1992).

The study of invertebrates in Africa has generally lagged behind that of vertebrates. Vertebrates are much easier to study than invertebrates because most species have been described, they are relatively large and easily distinguished from each other, and adequate identification guides and checklists are available for most groups. In contrast, invertebrates tend to be small and almost invariably require the use of a microscope for accurate identification. Consequently, most of them cannot be readily identified by laymen and specimens have to be sent to specialists for identification which frequently leads to considerable delays in preparing species lists. In addition to these disadvantages, there are few readily accessible identification guides and for most groups it is necessary to consult primary taxonomic literature.

The lack of adequate guides has been a particularly acute problem in Africa, where for many years the only general guide to aquatic invertebrates was Durand and Lévêque (1980, 1981), which had the disadvantage for southern African readers of being written in French and covered only the West African savanna region. The situation in southern Africa is now improving with the appearance of a 10-volume series of identification guides published by the South African Water Research Commission, five of which have now been published (Day *et al*. 2000, 2001a, 2001b, Day & de Moor 2002a, 2002b).

Relatively little is known about aquatic invertebrates in any of the waters of the Four Corners area. The area has until very recently been remote from major centres with active museums or universities and has only been visited by collectors rather than ecologists. Most of the ecological work done so far has concentrated on large mammals, fish, vegetation or human health problems such as tsetse flies or bilharzia snails.

12.2 HOW MANY SPECIES ARE THERE?

Although the total number of invertebrates is very large, the number of species that occur in freshwater tends to be relatively low. For example, just over 800 species of macro-invertebrates[1] have been recorded from Namibian wetlands, compared to about 320 species of vertebrates (Table 12.1). At first sight, this suggests that the differences in our level of knowledge of the two kinds of animals should be relatively small, but this is not the case. Most vertebrate species are known, and only a few new species are likely to be discovered in future years. Most of them are

1 The term 'macro-invertebrates' is generally used to distinguish multicellular invertebrates from the unicellular animal-like protists (also known as protozoans). Some multicellular animals, such as the Rotifera, are all microscopic in size and have also been excluded from the table.

Table 12.1. The number of families and species of freshwater macro-invertebrates and vertebrates recorded from Namibian wetlands.
From Curtis *et al.* (1998), Branch (1988), Maclean (1984) and Smithers (1986).

Phylum	Class	Subclass/Order	Families	Species	Endemics
Porifera			2	3	0
Cnidaria			2	2	0
Platyheminthes			6	9	0
Ectoprocta			2	5	0
Nematoda			6	10	1
Annelida	Oligochaeta		5	13	1
	Hirudinea		3	16	3
Mollusca	Gastropoda		9	26	0
	Bivalvia		5	13	0
Arthropoda	Crustacea	Ostracoda	3	52	18
		Copepoda	2	19	1
		Anostraca	3	19	6
		Cladocera	5	19	1
		Notostraca	1	2	0
		Conchostraca	6	15	3
		Amphipoda	2	6	6
		Isopoda	1	4	4
		Decapoda	3	6	0
	Insecta	Ephemeroptera	6	19	0
		Plecoptera	1	2	1
		Trichoptera	6	35	3
		Odonata	10	77	0
		Diptera	13	179	14
		Neuroptera	1	1	1
		Coleoptera	10	200	17
		Hemiptera	12	45	3
		Orthoptera	2	7	0
Total Invertebrates			127	804	83
Chordata	Actinopterygii		19	115	2
	Amphibia		7	50	0
	Reptilia		4	13	0
	Aves [1]		32	131	0
	Mammalia		6	10	0
Total vertebrates			68	319	0

[1] Includes bird species that inhabit wetland areas, even if they do not feed in water. Many are migratory and do not breed in Namibia.

relatively easy to identify and for most groups there are a considerable number of people (both lay and professional) who are able to make identifications. Their distribution and habitat requirements are broadly understood and some have been studied in detail, both at the species and the community level.

In contrast, the number of invertebrate species is undoubtedly an underestimate and many more species remain to be discovered especially in little known or highly speciose groups (such as the free-living nematodes, or beetles and flies, respectively). Most need to be identified by specialists and workers in the field are often able to identify them only to family level. The distribution of most species is poorly known and a high proportion of them are only known from their type locality so little can be said about their zoogeography or habitat requirements. Finally, few detailed investigations of invertebrates have been carried out in comparison to the work done on vertebrates. The need to increase our knowledge of aquatic invertebrates in southern Africa as a whole, and the Four Corners region in particular, is a major challenge for freshwater biologists.

Most of the data on aquatic invertebrates comes from collections in museums. Such data have probably been reported in the primary taxonomic literature, which is not always easy to locate and is frequently unavailable in libraries in the region as it is often published in European or North American museum journals, which may have a limited circulation in the region. A good example of this problem is the paper on haliplid and dytiscid beetles by Bilardo and Rochhi (1997) published in an Italian journal that may not be available in any southern African library. This makes it difficult and time-consuming to assemble checklists of species and although such lists are an essential preliminary to understanding species richness and biodiversity few can be said to give a complete, or even relatively complete, picture of the invertebrate fauna.

Namibia is the only country in the Four Corners area for which anyone has attempted to list the aquatic invertebrate fauna or assess its species richness (Curtis 1991, Curtis *et al*. 1997). These are valuable syntheses of existing knowledge and as much as anything else draw attention to the gaps in our knowledge of aquatic invertebrates. These lists provide the most comprehensive checklists for any part of the Four Corners area, giving totals of 118 and 126 species from East Caprivi and the Kavango River, respectively (Table 12.2). This is well below the total number that can be expected to occur in the area, partly because of a lack of adequate collecting but also because of collecting biases (which are, of course, recognised by the authors). Three examples clearly illustrate the effect of these collecting biases:

A. No chironomid species (Diptera; Chironomidae) are listed from either East Caprivi or the Kavango River, although 27 species have been recorded elsewhere in Namibia. It is inconceivable that chironomids are absent from these systems since they are commonly found in all freshwaters and their absence reflects the fact that no one has collected them in these systems. Some indication of what might be expected can be obtained from other sources. In Lake Kariba McLachlan (1969a) recorded 18 named species, and recognised 16 others that he was unable to identify to species level. At least that number could be expected from almost any water body in the Four Corners area; possibly more because Lake Kariba was still young when McLachlan worked there and had not developed diverse environments such as macrophyte beds where a greater diversity of chironomids might be expected (McLachlan 1969b). Palmer (1996) recorded 30 species from the Orange River, while de Moor *et al*. (2000) collected 64 species from the Cunene River, although they were sampling an area that probably has greater habitat diversity than most sites in the Four Corners.

Table 12.2. An estimate of the numbers of families and species of invertebrate groups in East Caprivi (Chobe-Linyati system) and the Kavango (Okavango) River, Namibia.
From Curtis (1991). Note that the taxonomic breakdown is for convenience only, and that the list also includes species not actually recorded but believed to occur in these systems.

			East Caprivi		**Kavango River**	
			Families	Species	Families	Species
Porifera		sponges	1	1	1	1
Cnidaria		hydra/jellyfish	1	1		
Platyhelminthes	Trematoda	flukes	3	6	3	3
	Turbellaria	flatworms				
Ectoprocta		moss animals				
Nematoda		round worms				
Annelida	Oligochaeta	segmented worms	4	7		
	Hirudinea	leeches	2	7	2	5
Mollusca	Gastropoda	snails	7	18	6	20
	Bivalvia	mussels	4	10	5	9
Crustacea	Ostracoda	seed shrimps	1	4		
	Copepoda	copepods	1	3	1	1
	Cyclopoidea	cyclopoids	1	1		
	Branchiopods	fairy shrimps	4	5	1	1
	Cladocera	water fleas	5	6		
	Decapoda	crabs/shrimps	3	3	2	3
Insecta	Ephemeroptera	mayflies	3	6	5	6
	Plecoptera	stoneflies			1	2
	Trichoptera	caddisflies			4	9
	Zygoptera	damselflies	1	3	6	18
	Anisoptera	dragonflies	3	10	3	19
	Diptera	flies	3	3	2	11
	Coleoptera [1,2]	beetles	4	28	2	15
	Hemiptera	bugs	6	6	3	3

[1] Appleton and Curtis collected about 30 spp. of Coleoptera in 6 families in the Okavango Delta during the first AquaRAP, and at least 10 spp. from 8 families of Hemiptera

[2] More Coleoptera have been identified from the Namibian section of the Okavango; see papers cited in Curtis 1998.

B. Curtis (1991) lists only six taxa of Hemiptera (water bugs) in six families from East Caprivi and three taxa in five families from the Kavango River, with nothing having been identified to species level. This is a very small number and intensive collecting would almost certainly reveal more of them. This can be illustrated by the fact that 16 species of Hemiptera (plus four unidentified ones) were collected from a series of pans in Hwange National Park, Zimbabwe (Weir 1966).

C. The impact of collecting bias is also strongly illustrated by the Odonata (dragonflies and damselflies). Curtis (1991) lists only 13 species from East Caprivi and 37 species from the Kavango River, which compares to 84 species from the Okavango Delta and 88 species from the Katombora-Victoria Falls section of the Zambezi River (Fitzpatrick 2000). The reason for this discrepancy is simple; Elliot Pinhey, the foremost authority on central African Odonata apparently did not collect much, if at all, in the Caprivi or Kavango River. Had he done so it is very probable that the number of dragonfly species known from the area would be similar to that recorded from the Okavango or upper Zambezi.

There is only one group of invertebrates for which it is possible to make a comprehensive list from the Four Corners region - the molluscs. This is because they are a relatively small group and have been the subject of detailed study owing to the fact that some species are vectors of human or animal diseases. Some 30 mollusc species (21 snails and 9 mussels) are known from the area (Table 12.3) and most of them seem to occur in each major water system. None is endemic and most are widely distributed Afrotropical species, although the Okavango Delta is the southernmost limit of some species (*Pila, Gabbiella*) and the most southerly limit of species that extend down to Natal along the east coast (*Bellamya, Lanistes, Cleopatra, Segmentorbis* and *Bulinus globosus*) (Brown *et al*. 1992). The distribution of the latter group is presumably determined by the arid conditions that occur to the south of the delta. The lack of endemic species is attributed to the absence of extensive stony rapids that have promoted prosobranch speciation in the so-called "high-energy" rivers commonly found in western Africa.

The ability to identify the molluscs has made it possible to make estimations of the relative abundance of various species (Table 12.4). It is clear that *Lymnaea natalensis* seems to be the most abundant snail in the system but the relative abundance of other species is highly variable. This may well be an artefact since the different authors used different sampling methods, except in the Okavango in Botswana and Namibia (Curtis 1997). Even here the relative abundance of snails was very variable and this may reflect differences in habitat or other factors.

These problems highlight the importance of well-planned and intensive sampling of aquatic invertebrates and the maintenance of comprehensive collections in museums leading, ultimately, to adequate guidebooks that could be used by field ecologists and others with an interest in invertebrates. An effort towards this has begun in the Okavango Delta through the AquaRAP programme, which involves intensive sampling of all biota at a fixed number of stations over a short period of time. This programme, which has been carried out twice, should make a contribution to expanding the list of invertebrates from this important wetland although the results of the first sampling programme are not yet been published. The second one was done early in 2003 and the results will probably not be available for some time (C.C. Appleton & P.G.H. Frost, pers. comm.).

12.3 WHAT IS KNOWN OF THEIR ECOLOGY?

Invertebrates make up much of the animal biomass in freshwaters and therefore make a crucial contribution to the functioning of these ecosystems. They are found on or in the substrate as well as amongst submerged vegetation, and also in open water where they constitute the zooplankton. They are responsible for much of the nutrient cycling in both standing and running waters where detritivores break up plant material and convert it into food for other invertebrates. Herbivores that scrape algae from rocks or plants, or graze on phytoplankton in open water help to influence the structure and productivity of these communities. Together they form complex food chains and are preyed upon by predaceous invertebrates, as well as vertebrates, especially fish and birds (but also certain mammals such as otters which feed on crabs).

Table 12.3. Freshwater molluscs of the Four Corners region.
From Brown *et al*. (1992), Appleton (1996) and Curtis (1997). The symbol * denotes species of medical or veterinary importance.

Family	Species	Okavango River	Okavango Delta	Chobe-Linyati	Upper Zambezi
Viviparidae	*Bellamyia capillata*	+	+	+	+
	Bellamyia monardi	+			
Ampullariidae	*Pila occidentalis*	+	+	+	
	Lanistes ovum	+	+	+	0
Hydrobiidae	*Lobogenes michaelis*			+	+
Bithyniidae	*Gabbiella kisalensis*	+	+	+	
Thiaridae	*Melanoides victoriae*	+		+	
	Melanoides tuberculata				+
Lymnaeidae	*Lymnaea natalensis**	+	+	+	+
	Cleopatra nsendweensis	+		+	+
	Cleopatra elata	+	+	+	
Ancylidae	*Ferrissea victoriensis*			+	+
Planorbidae	*Afrogyrus coretus*	+	+	+	
	Gyraulus costulatus	+	+	+	
	Segmentorbis angustus		+	+	
	Segmentorbis kanisaensis	+			
	*Biomphalaria pfeifferi**	+	+	+	+
	Bulinus scalaris	+	+		
	*Bulinus globosus**	+	+	+	
	Bulinus depressus	+	+	+	
	*Bulinus tropicus**	+		+	+
Unionidae	*Caelatura kunenensis*	+	+	+	+
Corbiculidae	*Corbicula fluminalis*	+	+	+	+
Mutelidae	*Mutela zambezensis*	+		+	+
	Aspatharia pfeifferiana	+			+
	Spathopsis wahlbergi	+	+	+	+
Sphaeriidae	3 species	+		+	+
	Eupera ferruginea	+			

Every aquatic environment has its own characteristic invertebrate fauna and their distribution and diversity is largely determined by the availability of suitable habitats. Not all aquatic species spend their entire life in the water and many insects have adults that leave the water, contributing in some instances to a significant exchange of nutrients between aquatic and terrestrial environments. Finally, many species are parasitic (often on fish or amphibians but also on higher vertebrates) and may be vectors of human or animal diseases.

Given the importance of invertebrates in aquatic systems, there can be little doubt of the need for detailed ecological studies but, throughout tropical Africa the ecology of invertebrates has received much less attention that that of vertebrates. The situation in the Four Corners area is especially acute where few ecological studies are available; for example, of the 5056 entries in the bibliography of African aquatic invertebrates compiled by Davies *et al*. (1982) only three relate to ecology anywhere in the Four Corners (Weir 1966, 1972, Seaman *et al*. 1978). Pinhey

(1976) gives ecological notes on dragonflies but these are largely descriptive as the paper is primarily a taxonomic work and not an ecological study. The effects of aerial spraying with endosulphan to control testes flies were considered by Russell-Smith and Ruckert (1981).

12.3.1 Pans in Hwange National Park

Weir (1966, 1969) worked in a series of small pans and pools in various parts of Zimbabwe, including some in Hwange National Park. He was primarily interested in Hemiptera and was able to establish some degree of ecological zoning amongst the species occurring in large pans (Table 12.4) and in shallow ephemeral pools. In these, the shallow marginal regions were inhabited by *Micronecta eupombe* and *Laccotrephes fabricii*, the central portion of open water by *Anisops debilis*, *A. sardea* and *A. jaczewski* while the neuston, usually at the margins, was occupied by *Mesovelia vittigera*, *Microvelia gracillima* and *Limnogonus hypoleuca*. This work gives a good indication of the complexity of invertebrate populations in even quite small water bodies.

In a later paper, Weir (1969) gives a striking illustration of the diversity of invertebrates in pans with some 21 major groups occurring although only three, Diptera (55.8%), Crustacea (16.12%) and Hemiptera (15.39%) were numerous, accounting for 87% of the total number of animals collected (Table 12.5). The productivity of the pans varied considerably, depending on their water chemistry and the amount of organic matter deposited in them by game animals (Table 12.6). The levels of productivity shown in the table are very high, in some cases equal to or exceeding those of well-managed fish ponds and indicate the importance of invertebrates in these aquatic systems.

One final aspect of Weir's work deserves consideration. He assessed the impact of the omnivorous catfish *Clarias gariepinus* on the invertebrate fauna of a pan in Hwange National Park into which it had been introduced. There was a dramatic reduction in the number of animals collected from the pan with fish, especially among the numerically dominant Hemiptera and Coleoptera (Table 12.7). Species richness was reduced as well with number of hemipteran species falling by 70% from 16 in the fishless pool to 5 in the pool with fish (Table 12.8) and the number of coleopteran species falling from 32 to 7, a decrease of 78% (Table 12.9).

12.3.2 Lake Liambezi

Lake Liambezi was a lake of about 300 km^2 (of which only about 100 km^2 was open water, the rest being reed swamp) located in the Eastern Caprivi on the border of Namibia and Botswana. It has an unstable history and maps published before 1950 show no open water but only a swamp. Open water apparently appeared after a drought when local people burnt the accumulated organic matter to create open water. During the 1970s and early 1980s it supported a small fishery that was nevertheless of considerable value to the local people. It dried up completely during the droughts of the late 1980s and 1990s.

Seaman *et al*. (1978) conducted a limnological survey of the lake which gave some data on aquatic invertebrates. The benthos was dominated by Chironomidae (66% of the total) and the oligochaetes *Ilyodrilus* and *Limnodrilus* (Table 12.10), which is typical of many lakes in southern Africa. No benthos was collected at station 4, but there were a large number (2917 /m^2) of snail shells there, mostly *Bulinus* spp., the commonest snail in the region. These data indicate the degree of variability amongst the benthos, and the impact of environmental factors such as the differences between the sandy and muddy parts of station 6. Station 4 may have been exposed to wind since benthos is generally scarce at exposed sites while empty snail shells tend to be carried by the wind and deposited on exposed shores.

Table 12.4. The apparent zonation of Hemiptera in large pans in Hwange National Park, Zimbabwe (modified from Weir 1966).

Zone	**1**	**2**	**3**	**4**	**5**
Depth (feet)	0-2	2-3	3-4	4+	Neuston
Micronecta eupompe	X				
M. scutellaris	X				
Micronecta nymphs		X			
Anisops jaczewski	X	X			
A. hancocki	X	X			
A. sardea		X	X		
A. debilis		X	X		
A. pellucens			X	X	
Anisops nymphs	X	X			
Laccotrephes fabricii	X				
Sigara wahlbergi			X	X	
Lethocerus cordofanus			X	X	
Agraptocorixa dakarica			X	X	
A. gestroi			X	X	
Mesovelia vitteriga					X
Limnogonus cereiventris					X
L. leptocerus					X

Zone 1: shallow, much recumbent green vegetation, *Lagarosiphon, Marsilea* and some algae.

Zone 2: region of emergent marginal vegetation, very dense reeds and rushes.

Zone 3: immediately outside the emergent marginal vegetation, often with *Nymphaea* or other water lilies.

Zone 4: central open water, muddy bottom. Much detritus and decaying organic matter.

Zone 5: neuston usually near littoral vegetation.

Table 12.5. The diversity (%) of invertebrates collected from 12 pans in Hwange National Park, Zimbabwe.
From Weir (1969).

		No of pans	**% by numbers**
Platyhelminths		5	4.63
Oilgochaeta		7	0.55
Hirudinea		1	0.03
Gastropoda		1	0.03
Crustacea	Conchostraca	7	7.18
	Anostraca	6	8.94
Zygoptera		7	1.42
Anisoptera		11	2.36
Hemiptera	Corixidae	10	1.39
	Notonectidae	9	13.27
	Ranatridae	2	0.15
	Hydrometridae	1	0.03
	Pleidae	2	0.55
Diptera	Chironomidae	11	41.62
	Culicidae	9	10.57
	Chaoboridae	1	0.33
	Tabanidae	2	0.06
	Syrphidae	3	3.30
Coleoptera	Hydrophilidae	10	2.51
	Dytiscidae	7	1.00
Hydracarina		2	0.09

Table 12.6. Estimates of standing crop and productivity in six pans in Hwange National Park, Zimbabwe. From Weir (1969).

Pool	Standing crop (after 6 weeks) (kg/ha)	Weekly production (kg/ha)	Potential production per 15 week season (kg/ha)
1	5	0.8	12.0
2	8	1.3	19.5
3	75	12.5	187.5
4	2	0.3	4.5
5	56	9.3	139.5
6	754	125.6	1884.0

Table 12.7. The impact of an introduced fish, *Clarias gariepinus*, on the fauna of pans in Hwange National Park.
The data are the numbers of specimens per sample made with a hand net. From Weir (1972).

	Fish absent	Fish present
Hemiptera	2196	51
Coleoptera	1070	15
Gastropoda	2	1
Ephemeroptera	1	
Zygoptera	2	
Chironomidae	2	
Amphibian tadpoles	1	
Total	3274	67

Table 12.8. The impact of the introduced fish *Clarias gariepinus* on the diversity of Hemiptera in pans in Hwange National Park, Zimbabwe.
From Weir (1972).

		Fish absent	**Fish present**
Notonectidae	*Anisops sardea*	907	32
	A. pellucens	710	
	A. varia	364	10
	A. debilis	48	2
	A. jaczewski	7	
	Nychia limpida	1	
Corixidae	*Agraptocorixa gestroi*	36	
	A. dakarika	21	4
	Sigara wahlbergi	12	
	S. contortuplicata	5	
	Unidentified nymphs	24	
Nepidae	*Laccotrephes fabricii*	3	
Belostomatidae	*Lethocerus cordofanus*	1	
	Sphaeroderma capensis	1	
Naucoridae	*Macrocoris flavicollis*	3	
Pleidae	*Plea pullula*	53	3
Total		2196	51

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Table 12.9. The impact of the introduced fish *Clarias gariepinus* on the diversity of Coleoptera in pans in Hwange National Park, Zimbabwe.
From Weir (1972).

		Fish absent	**Fish present**
Dytiscidae	*Canthydrus notula*	9	1
	C. quadrivittatus	3	
	Hydrocanthus ferruginicollis	64	1
	H. grandis	2	
	Hydrovatus badeni	67	1
	H. obsoletus	1	
	Hydrovatus sp. 1	15	
	Hydrovatus sp. 2	4	
	Hydrovatus sp. 3	55	
	Hyphydrus grandis	2	
	H. impressus	13	
	H. aethiopicus	1	
	Laccophilus continentalis	322	2
	L. vermiculosus	29	
	L. simplicistristus	14	
	L. flaveolus	14	
	Guignotus transvaalensis	5	
	Yola dohrni	266	2
	Y. tuberculata	1	
	Herophydrus gigas	23	
	H. guineensis	5	
	Eretes sticticus	24	
	Rhantaticus congestus	4	
	Cybister senegalensis	2	2
	C. tripunctatus	2	6
Hydrophilidae	*Allocotocerus subaenus*	2	
	Regimbartia compressa	6	
	Amphiops senegalensis	1	
	Berosus kalahariensis	102	
	B. vitticollis	1	
	Synchortus sparsus	11	
Total		1070	15

Table 12.10. The zoobenthos (no/m^2) collected at five stations in Lake Liambezi in July 1974**.**
From Seaman *et al*. (1978).

	1	**2**	**3**	**4**	**6 (sandy)**	**6 (muddy)**	**% of total**
Chironomidae	1583	1333	417		4667	4000	66.1
Ceratopoginidae	83	83	83		667		5.0
Chaoborus	333						1.8
Ephemeroptera		83			333	167	3.2
Trichoptera						167	0.9
Zygoptera						167	0.9
Hirudinea						167	0.9
Ilyodrilus	1000	500	167		667		12.8
Limnodrilus	83	83			1333		8.3
Total	3082	2082	667	0	7667	4668	

The zooplankton was dominated by the small cladoceran *Bosmina longirostris* whilst the dominant rotifers were various *Brachionus* species, including *B. calyciflorus, B. falcatus, B. caudatus* and *B. quadridentatus*. Other members of the zooplankton included copepods (*Diaptomus congruens* and *Thermocyclops* sp.), cladocerans (*Ceriodahnia reticulata, Moina dubia, Diaphanosoma excisum, Chydorus* sp., *Alona* sp., *Macrothrix* sp. and *Pleuroxus* sp.), rotifers (*Tetramastix opoliensis, Filinia pejleri, Trichocerca* sp., *Aneuriopsis fissa, Mytilina ventralis, trichocerca chattoni, Asplanchna* sp., *Keratella tropica, K. cochlearis, Hexarthra* sp., *Epiphanes* sp. and *Lecane luna*), and the freshwater jellyfish *Limnocnida tanganyicae*.

The composition of the zooplankton was therefore very similar to that of Lake Kariba and other reservoirs in the region being made of species that have a wide distribution in Africa (Green 1985, 1990, Elenbaas & Grundel 1990). It was also very similar to Lake Kariba in being dominated by small species (*Bosmina* and rotifers) suggesting that there was intensive predation by fish, which typically leads to the reduction or elimination of the larger species. There was also some indication of vertical migration by the zooplankton although the patterns were not consistent, varying with time and amongst species. It was not possible for the authors to determine the factors that were influencing these movements.

12.3.3 The Effects of Endosulphan

The insecticide endosulphan has been used to control tsetse flies in the Okavango Delta where large areas were sprayed from the air. Although it is a non-residual insecticide there were concerns about its impact on non-target organisms, including aquatic forms (Russell-Hunter & Ruckert 1981).

They first examined zooplankton in lagoons and found an annual cycle in the rotifers that may have been seasonal, or may have been related to water level, because the numbers of zooplankton were lowest from August-November, a time when the water levels were at their peak. The effect of spraying with endosulphan on rotifer populations was not clear (Table 12.11).

Table 12.11. The mean percentage of different rotifer species in plankton samples taken three months before and three months after the spraying season in 1976.
From Russell-Hunter & Ruckert (1981).

	Pre-spray		**Post-spray**	
	Sprayed	Control	Sprayed	Control
Filina sp.	3.8	3.6	0.3	0.0
Branchionus sp.	1.3	0.2	0.3	0.2
Keratella sp. A	3.9	6.3	3.9	0.2
Keratella sp. B	2.3	2.5	1.6	0.4
Polyarthra sp.	20.5	17.1	13.2	8.4
Hexarthra sp.	11.3	10.8	23.6	11.7

The relative numbers (proportions) of all rotifers, with the exception of *Hexarthra* sp. which increased in the sprayed lagoon and *Keratella* sp. A, which fell in the unsprayed lagoon. It could not be clearly demonstrated whether these changes were caused by spraying or whether they reflected some natural phenomenon. Something similar occurred with the crustacea, which were sometimes more abundant in the sprayed lagoons and sometimes less abundant.

Animals living amongst the periphyton (oligochaetes, chironomids, trichoptera and ephemeroptera) were all reduced in numbers during the spraying cycle in 1977, but not to the same extent in 1978. In this year only oligochaetes numbers fell in the sprayed lagoons, while the numbers of the other groups were lower in unsprayed lagoons. The number of chironomids in a sprayed lagoon had recovered completely within 10 months of spraying (Table 12.12).

Table 12.12. The mean numbers of chironomid larvae from periphyton samples in Manxunyane Lagoon, Okavango delta, 1977-1978.
From Russell-Hunter & Ruckert (1981).

August 1977 (Pre-spray)	October 1977 (Post-spray)	August 1978 (Post-spray)
44.2 ± 24.4	21.9 ± 9.5	98.9 ± 23.4

More research work has undoubtedly been done in the Four Corners area since Davies *et al.* (1982) was published but it has not been easy to locate the results of it, which suggests that the situation has not improved significantly over the last 20+ years. There remains an urgent need for more intensive investigations into the ecology of aquatic invertebrates in the Four Corners area in order to understand the aquatic systems better. General surveys like the AquaRAP programme can give valuable data but they can be no substitute for thorough long-term investigations that are the only way to obtain a clear insight into the functioning of the system and an understanding of the way it responds to change, from which adequate conservation policies can be developed.

12.4 SITES OF SPECIAL INTEREST

Given our current level of knowledge, it is difficult to identify sites of special interest in relation to aquatic invertebrates. The pan system of Hwange National Park is certainly an important one that supports a diverse invertebrate fauna, although probably without any endemic species, and is vulnerable to mismanagement such as the introduction of exotic fishes. There may also be pan systems elsewhere in the region, especially in its more arid southern sections that could support endemic branchiopods and ostracods.

Otherwise, provided the major water systems remain intact, there seems to be little need to preserve areas because of their aquatic invertebrate fauna. Invertebrates obviously respond to environmental changes, such as the growth (or loss) of submerged vegetation, changes to the substrate, or the impacts of fish, but most species are mobile and will not be threatened as a whole.

12.5 RESEARCH ISSUES FOR CONSERVATION AND MONITORING

Conservation is not possible without knowing what has to be conserved, and the most important research issue from a conservation point of view is to expand our knowledge of aquatic invertebrates. Unfortunately, the importance of invertebrates is not always recognised and it is difficult to obtain funds for research, except perhaps for the control of species of medical importance. There is therefore an urgent need for more funding and an increase in the numbers of people trained in invertebrate biology in the museums and universities of the region. There also needs to be a change in funding allocations from short-term projects, often linked to some developmental goal, to long-term investigations into the basic ecology of the inland waters of the area.

Important areas of research include invertebrate taxonomy in order to learn more about their species composition and distribution, to determine the existence of endemic species or those with restricted distributions. The ecology of invertebrates, both to understand how the ecosystems in the Four Corners area function, and in relation to fish production also needs more study. The impact of human activities, especially in relation to the control of pest species such as malaria (Namibia and Zimbabwe use DDT for malaria control), tsetse flies or bilharzia snails also raises many questions. The same applies to human-induced changes in the area such as agricultural development, drainage of wetlands or flow diversion, or the introduction of alien species (which includes invertebrates, which may be less obvious but as dramatic in their impact as that of vertebrates) which all need to be understood more clearly.

The idea of monitoring is often raised without any clear idea of what exactly is to be monitored and for what purpose. Periodic surveys designed to produce so-called 'baseline' data are of some value but, without fundamental understanding of ecological processes, will not always be able to explain whether changes are real or transitory. Monitoring programmes should therefore be carefully designed, long term investigations that can address questions about the diversity, distribution and variation of invertebrate populations. Aquatic invertebrates can be used as indicators of water quality; a form of monitoring that is becoming increasingly widespread in southern Africa. The most widely used system is the SASS (South African Scoring System) which evaluates invertebrates, identified to family level only, on the basis of their pollution sensitivity and produces an index of water quality based on a combination of that sensitivity and an estimate of relative abundance (Thirion *et al*. 1995, Chutter 1998). While designed by South African scientists, the system has proved its applicability elsewhere, as in Zimbabwe (Gratwicke

1998/99), but it does have some limitations. The most important is that it was designed for use in stony riffles and its applicability to the large rivers and floodplain systems that make up most aquatic habitats in the Four Corners his still to be demonstrated, although recent improvements to the methods suggests that it could be used in them (Dickens & Graham 2002).

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