Freshwater Crustacea (Ostracoda, Copepoda, Branchiopoda, Cladocera) of the Cuvelai wetlands in northern Namibia

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The aquatic crustaceans of the shallow water courses and pools of the seasonal Cuvelai wetlands were sampled during the wet season of 1996-1997. Ten copepod, six anostracan, one notostracan, seven conchostracan, and thirteen cladoceran species were identified, of which fourteen represent first records for Namibia.

INTRODUCTION

The Cuvelai drainage basin arises in the central highlands of Angola and ends in the Etosha Pan in Namibia (Figure 1). From the Angolan-Namibian border it is flat and sandy with elevations decreasing very gradually to the pan (about 30 m drop over 160 km). Seasonal wetlands are formed as water drains through a complex network of shallow water courses or *oshanas* covering approximately 10,000 km^2. The *oshanas* converge into a series of pans at Lake Oponono and in exceptional flood years water flows down the Ekuma River to the Etosha Pan. Local rainfall and water from the upper catchment contribute to the sluggish unpredictable flow of the *oshanas*. The climate is semi-arid with 99% of the rain (400-500 mm per year) falling from October to April.

A basic description of the ecology of the Cuvelai system is given by Lindeque & Archibald (1991), although the emphasis is on Etosha. Records of invertebrates found in the seasonal wetlands of the former Owambo and Etosha are listed by Curtis (1991). Fish life and hydrology are described by Van der Waal (1991) who listed 17 species indigenous to the Cuvelai. Floodwaters from the upper catchment in Angola bring young fish which colonise the *oshanas*. Marsh & Seely (1992) summarise the basic environment and land use. The area has a high population and woodland and pasture resources are heavily utilised. Infrastructure such as roads, pipelines, canals and dams also threaten to change the natural wetland system.

The aim of this study was to provide baseline data on the aquatic invertebrates of the Cuvelai to allow future monitoring.

STUDY AREA

In order to interpret seasonal patterns in the freshwater invertebrate fauna of the Cuvelai system eight of the shallow water courses or *oshanas* and associated pools were sampled, together with a deeper pool or *ondombe* at Oshikuku (Figure 2). *Oshana* water courses stretch for several kilometers and in times of flood are connected through complex side channels. An *oshana* is bordered by a wide flat floodplain dominated by short grasses. The main channels, several hundred metres wide, contain water for much of the wet season (January to May) up to one metre deep but only flowing for a short period. Shallow water is dominated by grasses (*Diplachne* spp.: Poaceae) and sedges (Cyperaceae), while deeper areas support *Nymphaea* lilies (Nymphaeaceae) and other aquatic plants (*vide* Clarke this volume). Where no distinct channel is present, they may resemble pans, being poorly vegetated and becoming saline as a result of evaporation. *Oshanas* often

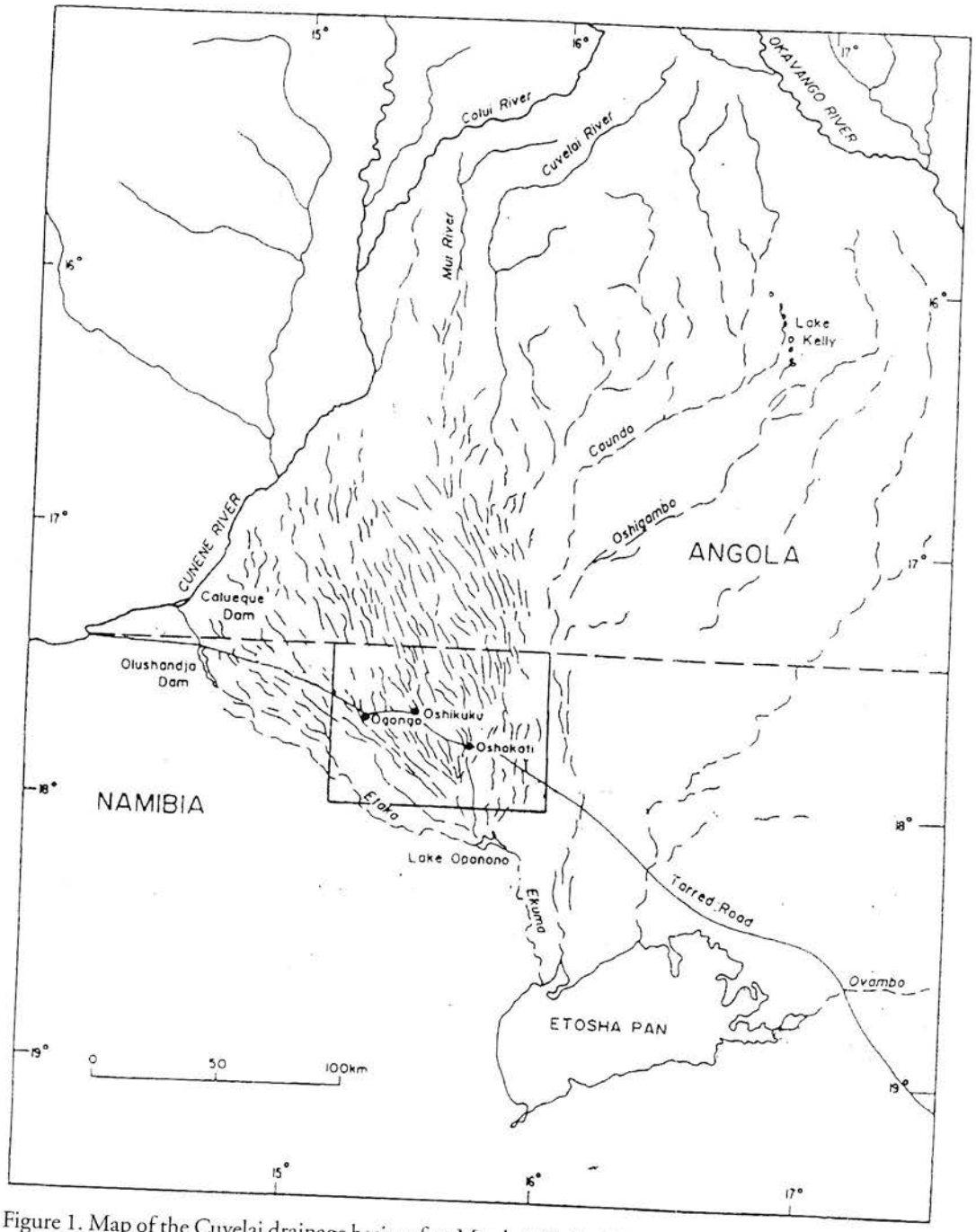

Figure 1. Map of the Cuvelai drainage basin, after Marsh & Seely 1992. *Vide* Figure 2 for enlargement of boxed area.

become flat expanses of bare sand in the dry season.

Pools are either isolated or adjacent to *oshanas*. *Ondombes* are larger (about 100 m diameter) and deeper (>1 m) pools, which have often been enlarged by people over a long period of time. They may retain water all year. They usually support a rich assemblage of emergent and floating aquatic plants. Characteristic trees such as *Diospyros mespiliformis* Hochst. ex A. DC. (Ebenaceae), *Hyphaene petersiana* Klotzsch (Arecaceae) and *Acacia hebeclada* DC. subsp. *tristis* A. Schreib. (Fabaceae) often grow on the banks.

Olushandja Dam is on the north-western edge of the Cuvelai (Figure 1). Roberts (1995) sampled plankton from a boat, and the samples taken were analysed during this study. The dam forms part of the water supply infrastructure. To provide a secure supply, water is brought from the Kunene River along an open canal to the town of Oshakati. At intervals there are purification plants, and pipelines distribute water to rural communities. The concrete canal passes through the north wall of Olushandja and some water is allowed to overflow into the dam for emergency storage. The canal water is kept separate from the *oshana* system, excepting for occasional floods, but an earth canal leaves the dam at the southern end and flows south-east where links with *oshanas* can occur. The water in the dam is fairly turbid but has low chemical and nutrient content (Roberts 1995). It is 20 km long and between 0.2 and 2 km wide with a maximum depth of 3.5 m. During the 20 years the dam has been in existence, the water level has been kept fairly stable and the marginal vegetation consists mainly of *Ludwigia stolonifera* (Guill. & Perr.) Raven (Onagraceae) and *Cyperus imbricatus* Retz. (Cyperaceae), with large reedbeds of *Typha capensis* (Rohrb.) N. E. Br. (Typhaceae) and *Phragmites mauritianus* Kunth (Poaceae) (Burke 1995).

Other habitats sampled included a section of an earth canal, north-west of Ogongo (17°38'45"S, 15°17'05"E). It is part of an abandoned water supply system that retains water for most of the year. It supports emergent aquatic plants and the water, generally less than one metre in depth, is less turbid than the *oshanas*. An excavated reservoir of about 200 m diameter was also sampled south-west of Ehangano (17°47'46"S, 15°37'10"E). The water was isolated from the *oshanas* by high banks and was sparsely vegetated and less turbid.

MATERIALS & METHODS

Site coordinates were determined using a Garmin GPS 75 navigation system. Water samples were taken in April and May 1997 from some sampling sites. One litre samples in polyethylene bottles were sent to the Department of Water Affairs laboratory at Windhoek for chemical analysis as soon as possible although this could take three weeks. Field measurements of temperature were also made during March, April and May 1997.

Nine sites were sampled (Figure 2) *viz.* Lashivanda, 17°28'17"S, 15°32'03"E, 1100 m (1); Shashimwaku, 17°26'50"S, 15°42'00"E, 1100 m (2); Ogongo, 17°38'17"S, 15°16'23"E, 1097 m (3); Ogongo East, 17°40'00"S, 15°23'00"E, 1096 m (4); Oshikuku, 17°39'29"S, 15°27'57" E, 1097 m (5); Sheenkombo, 17°42'40"S, 15°33'20"E, 1095 m (6); Shashuuli, 17°47'20"S, 15°21'00"E, 1098 m (7); Elim junction, 17°47'22"S, 15°30'10"E, 1094 m (8); Ehangano, 17°47'30"S, 15°37'30"E, 1094 m (9).

Aquatic invertebrates were collected using two net mesh sizes (0.5 mm, and 3 mm). Five sweeps of each net were made in the shallow margins and in the open water. *Oshana* and *ondombe* sample sites were visited in rotation each month from January to May 1997. The samples were preserved in 75% ethanol.

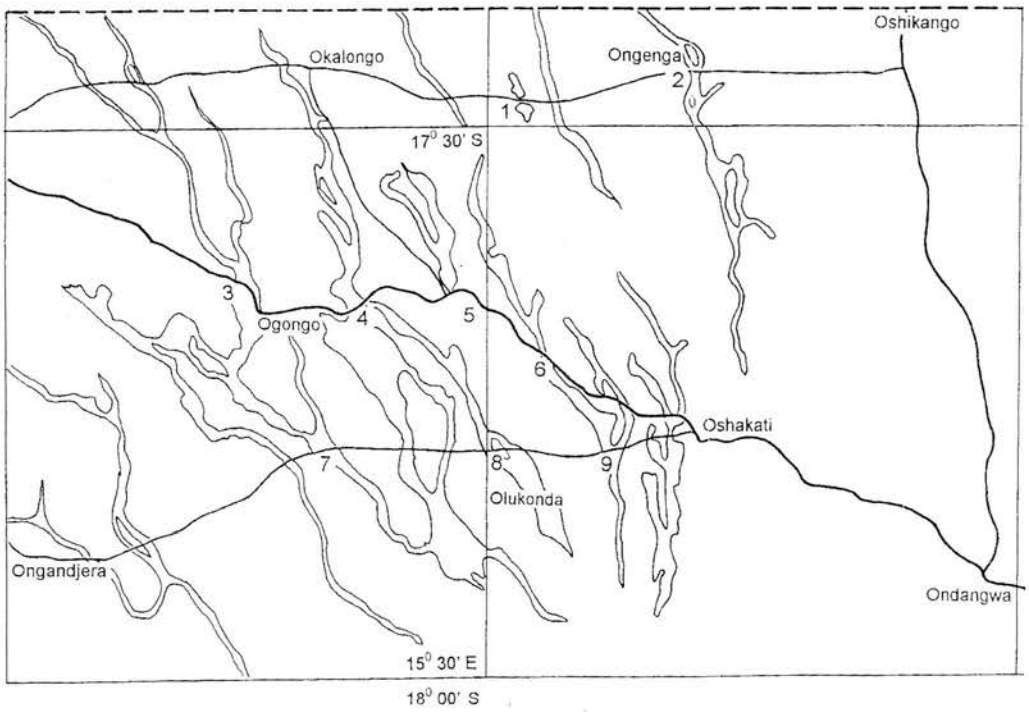

Figure 2. Map of sampling area: 1. Lashivanda; 2. Shashimwaku; 3. Ogongo; 4. Ogongo East; 5. Oshikuku; 6. Sheenkombo; 7. Shashuuli; 8. Elim junction; 9. Ehangano.

Voucher specimens resulting from this study are deposited at the National Museum of Namibia, Windhoek.

RESULTS

Table 1 compares average values for the major ions with their ranges for *oshanas*, *ondombes* and the Kunene River. *Oshanas* have consistently higher values as well as the greatest range of variation. *Ondombes* have intermediate values while the Kunene River has the lowest concentrations and the least range of variation similar to Olushandja Dam (Roberts 1995).

The order of dominance of the major cations was quite different for *oshana* water and river water. The samples from Kunene River (and Olushandja Dam) gave Ca>Mg>Na>K, however, the *oshanas* and *ondombe* samples were either Na>K>Mg>Ca or K>Na>Mg>Ca.

Oshanas have very high turbidity and colour from suspended clay particles. Where *oshanas* were sampled again at the end of the wet season, the effects of evaporation had increased salt concentrations.

Thermal stratification was normally recorded in the *oshanas* and *ondombes* under conditions of little or no flow. In March surface temperatures reached 35°C in the middle of the day while temperatures 20 cm below the surface were between 1 and 7°C degrees cooler.

Appendix 1 lists the crustaceans found in the study by habitat. Not all samples of ostracods have been identified as yet.

Table 1. Range of values for the major ions in different Cuvelai wetland habitats

Habitat	Values	Na mg/1	K mg/1	Ca mg/1	Mg mg/1	SO_4 mg/1	Cl mg/1	$Si0_2$ mg/1	Cond mg/1
oshana	average	100	79	4	25	85	87	26	52
24 samples	range	5-375	4-380	1-17	4-50	11-285	9-330	3-92	5-189
ondombe	average	31	23	15	23	28	23	14	18
4 samples	range	8-73	11-42	10-17	13-42	9-42	6-63	8-21	8-42
river	average	5	3	15	12	2	1	11	7
4 samples	range	4-5	3-4	13-15	8-17	0-3	0-2	7-16	5-10

DISCUSSION

The *oshanas* and *ondombes* exhibited a similar zonation to ephemeral pools studied by Hamer & Appleton (1991). The shallow edges were favoured by detritus feeders, dominated by *Triops granarius*, the two conchostracans, *Caenestheriella australis* and *Leptestheria rubidgei* and ostracods. The deeper water column was occupied by filter-feeders dominated by the two anostracans, *Streptocephalus macrourus* and *S. indistinctus*, as well as calanoid copepods and cladocera.

At the onset of the wet season (19 November 1996) samples were taken from shallow *oshana* rain pools. These were formed after a single rainfall event a week earlier. They contained *Triops granarius*, cladocerans and conchostracans but by 26 November 1996 the pools had dried-up, an example of density-independent mortality.

Oshanas were refilled by January and *Triops granarius* was recorded in virtually all the sampled sites. It was first recorded in the study area (the combined *oshana* sites) on 13 January 1997, but was not recorded after 5 February 1997. This approximate period of 24 days represents the completion of the life cycle. These results compare well to the study by Hamer & Appleton (1991), in which *Triops granarius* was shown to have initially reproduced after 7 days and to have a maximum lifespan of 26 days. Seaman *et al.* (1991) located the first females with eggs after a 6 day period and found adult survival extended to approximately 30 days, after which there occurred a sharp die-off.

Six species of conchostracans were identified from the study area (the Order Conchostraca is in need of taxonomic revision). The two dominent species of conchostracans in the *oshanas* were *Caenestheriella australis* and the larger *Leptestheria rubidgei*. They were common throughout the wet season but reached their peak abundance during the first month. In *ondombes Caenestheriella australis* was found to be extremely abundant.

Caenestheriella australis was recorded by Barnard (1929, 1935), as being widely distributed in the

drier areas of Southern Africa, with records from Northern Cape, Kalahari, Free State, Mpumalanga, Zimbabwe, Namaqualand, Damaraland, Ovamboland and Kaokoveld. *Leptestheria rubidgei* has been recorded (Barnard 1924, 1929) from Great Namaqualand and a number of localities in the Northern Cape and the Kalahari. *Leptestheria striatoconcha* was recorded by Barnard (1929) as a large species (9x6 mm) widely distributed in Ovamboland. *Cyclestheria hislopi* was recorded by Barnard (1924, 1935) from the Kalahari, Ovamboland, Zimbabwe and Mocambique. Historical records of this species from India and Sri Lanka must be regarded as suspect. *Lynceus pachydactylus* was recorded by Barnard (1929) from Npumalanga. *Lynceus truncatus* was recorded by Barnard (1924, 1929) from Ovamboland and Rayner & Bowland (1985) recorded it from an animal wallow in Umfolozi Game Reserve, Kwa-zulu Natal. *Lynceus bicarinatus* was not collected in this study, but Barnard (1924, 1929) recorded it from Ovamboland and it has been collected at Tari Kora waterhole in Kaudom Game Park, Namibia (Rayner, N.A. pers. obs.).

The open water of the *oshanas* and *ondombes* was dominated by the two common anostraca (*Streptocephalus macrourus* and *S. indistinctus*). Of the anostracan samples sent for identification 21 out of 25 contained one or both of these species. It is interesting to note, that these two species have also been observed together in Free State pans in South Africa (Seaman M.T., pers. com.). They first appeared in the *oshanas* on 13 January 1997. Numbers had declined by 28 February 1997 (46 days) but both species persisted in small numbers until 13 May 1997 (120 days). In the study by Hamer & Appleton (1991) initial reproduction of *Streptocephalus macrourus* (which has since been described as a new species; *S. bidentatus*, Hamer, M.L. pers. com.), occurred between 18 and 26 days (being habitat dependent) and maximum lifespan was between 54 and 110 days. Seaman *et al.* (1995) found initial reproduction at 6 days and a life span of 48 days for *S. macrourus*.

Hamer & Appleton (1991) postulated that edge zone crustaceans had shorter life cycles than central zone crustaceans, due to the fact that the edge zone is subject to dessication sooner than the central zone, while the marginal vegetation supports a more abundant insect predator fauna. The results of this study follow the same pattern. A decline in larger crustaceans coincided with the appearance of insects which are known to be predaceous on other aquatic invertebrates such as large dytiscid beetles (Coleoptera), naucorid bugs (Hemiptera) and nymphs of the families Coenagriidae, Lestidae, Aeshnidae and Libellulidae of the order Odonata. Notonectids (Hemiptera) gradually increased in the central open water zone during March, corresponding with a decline in the anostracans. Fish were also present in *oshanas* at this time, with the larvae of *Barbus paludinosus* Peters, 1852 (Cyprinidae) beginning to appear by mid-February.

Other species of Anostraca were only found infrequently in the study area. Two species were found in isolated excavated reservoirs and they occurred at a time when anostracans were at low densities in *oshanas*. Anostraca were absent in Olushandja Dam and earth canal samples, presumably due to the presence of fish.

The crustacean plankton was dominated by calanoid copepods and a small number of cladoceran species. The calanoid, *Lovenula falcifera*, was found in virtually all sites including the more saline pans. It has a wide distribution throughout Africa (Rayner *et al.* 1995), occurring in temporary, often saline waters on the high plateau (> 1000 m). It also exhibits the ability to colonise man-made impoundments (Rayner 1992; Rayner & Heeg 1994). After a month following the onset of the rainy season, *Lovenula falcifera* was abundant in the plankton of the *oshanas* and *ondombes* and remained so

for the rest of the wet season. This large predatory calanoid was usually accompanied by a smaller calanoid species, which forms the prey (Rayner & Heeg 1994). *Metadiaptomus meridianus* was recorded on 16 occasions, 10 in association with *L. falcifera*. Of the six *Thermodiaptomus congruens* records, five were in association with *L. falcifera*. On two occasions, *L. falcifera* was associated with two other calanoid species, a rather unusual occurrence as there is seldom more than two calanoid species in a waterbody (Rayner & Heeg 1994).

Thermodiaptomus congruens was originally collected from Ovamboland but has further been recorded from the Caprivi (Lake Liambezi, Seaman *et al.* 1978) and Angola (Kiefer 1937). Its distribution, therefore, extends both eastwards and northwards. *Metadiaptomus meridianus* is a widespread species in Southern and east Africa, while *M. colonialis* is a warm water species which extends as far north as Ethiopia. *Paradiaptomus schultzei* is widely distributed in drier areas of South Africa, Namibia, East Africa, Senegal and Ethiopia (Rayner & Heeg 1994).

The most abundent cladoceran sampled was *Daphnia barbata*. This species is widely distributed in Africa and is associated with shallow turbid pans (Rayner *et al.* 1995). Scholtz *et al.* (1988) suggest that predation by fish is probably a more important factor than turbidity in determining the presence of *D. barbata* rather than other *Daphnia* species. The fish *Barbus paludinosus* and *Clarias gariepinus* Burchell, 1822 (Clariidae) both colonised study sites during the wet season. *Moina* species were abundant. *Diaphanosoma excisum* is the common species of the genus occurring in Southern Africa, and was found in the more permanent habitats (Olushandja Dam and the earth canal). *Diaphanosoma brachyurum* was only found in the *oshanas* and is a new record for Southern Africa. *Diaphanosoma* species probably feed on very fine particles and bacteria and are associated with the inflow of allochthanous material (Rayner *et al.* 1995).

Non-planktonic Cladocera such as *Simocephalus vetulus, Euryalona colleti* and the macrothricids were associated with vegetation and detritus as were the cyclopoid copepods and ostracods. Very few cyclopoid species were collected. *Mesocyclops major* is widely distributed throughout Africa (Van der Velde 1984), while *Thermocyclops emini* is a species of tropical Africa and has been further recorded from Egypt (Kiefer 1978).

All the species collected in this survey are adapted to the stressful conditions associated with temporary waters. They are subjected to high water temperatures and must produce resting eggs or stages that are able to withstand desiccation.

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Appendix 1. Freshwater Crustacea of the Cuvelai wetlands. Identified by N.A. Rayner, M.L. Hamer and K. Martens. N =not previously recorded by Curtis (1991)

Crustacea	Habitat				
	Oshana	*Ondombe*	Olushandja dam	Reservoir	Earth Canal
Class: Ostracoda					
Family: Cyprididae					
Plesiocypridopsis cf. *aldabrae* (G.W. Müller, 1898)	x				
Pseudocypris gibbera Sars, 1924	x				
Sclerocypris dumonti Martens, 1988	x				x
Sclerocypris exserta Sars, 1924	x				
Class: Copepoda					
Order: Calanoida					
Family: Diaptomidae					
Lovenula Falcifera (Loven, 1845)	x	x		x	
Metadiaptomus colonialis (van Douwe, 1914)	x				
Metadiaptomus meridianus (van Douwe, 1912)	x	x			
Paradiaptomus schultzei van Douwe, 1912	x				
Thermodiaptomus congruens (Sars, 1927)	x	x	x		
Tropodiaptomus capriviensis Rayner, 1994					N
Tropodiaptomus schmeili (Keifer, 1926)	N				N
Order: Cyclopoida					
Family: Cyclopidae					
Mesocyclops major (Sars, 1927)	x		x		x
Microcyclops inopinatus (Sars, 1927)			x		
Microcyclops sp.	x				
Thermocyclops emini (Mrazek, 1895)	N				N
Thermocyclops sp.	x				
Class: Branchiopoda					
Order: Anostraca					
Family: Branchipodidae					
Branchipodopsis cf. *wolfi* Daday, 1910	x				
Family: Streptocephalidae					
Streptocephalus indistinctus Barnard, 1924	x	x			
Streptocephalus macrourus Daday, 1908	x	x			
Streptocephalus ovamboensis Barnard, 1924	x				
Streptocephalus proboscideus (Frauenfeld, 1873)				x	
Streptocephalus cladophorus Barnard, 1914				x	

Appendix 1. cont. Freshwater Crustacea of the Cuvelai wetlands. Identified by N.A. Rayner, M.L. Hamer and K. Martens. N =not previously recorded by Curtis (1991)

Crustacea	Habitat				
	Oshana	*Ondombe*	Olushandja dam	Reservoir	Earth Canal
Order: Notostraca					
Family: Triopsidae					
Triops granarius (Lucas, 1864)	x	x			
Order: Conchostraca					
Family: Cyzicidae					
Caenestheriella australis (Loven, 1847)	N	N			
Family: Cyclestheriidae					
Cyclestheria hislopi (Baird, 1859)	x	x			x
Family: Leptestheriidae					
Leptestheria rubidgei (Baird, 1862)	x				
Leptestheria striatoconcha Barnard, 1924	x				
Family: Lynceidae					
Lynceus pachydactylus Barnard, 1929	N				
Lynceus truncatus Barnard, 1924					x
Order: Cladocera					
Family: Chydoridae					
Euryalona colleti Sars, 1895	N	N			
Family: Daphniidae					
Ceriodaphnia rigaudi Richard, 1894			x		
Daphnia barbata Welthner, 1897	x	x	x		
Simocephalus capensis Sars, 1895	N				
Simocephalus exspinosus (Koch, 1841)		N			
Family: Macrothricidae					
Echinisca capensis Sars, 1916		N			
Macrothrix propinqua Sars, 1909	N				
Macrothrix spinosa King, 1852	N				
Leydigia macrodonta Sars, 1916	N	N			
Family: Moinidae					
Moina micrura Kurz, 1874	x	x			x
Moina tenuicornis Sars, 1896	N	N			
Moina sp.			x		
Family: Sididae					
Diaphanosoma brachyurum (Lieven, 1848)	N				
Diaphanosoma excisum Sars, 1886			x		x