The effect of the artificial linkage between the Kunene River and the Cuvelai system on the fish fauna in Owambo, Namibia.

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ABSTRACT

A concrete canal, built in 1972 to supply water from the Kunene River to the central parts of Owamboland, is responsible for the transfer of 32 fish species from the Kunene River to Owambo. Most of these fish are at present limited to artificial reservoirs. Only one cichlid species has so far successfully invaded the oshana system. Turbidity is believed to be the main factor preventing the invasion of Kunene River fish into the oshanas. A total of 22 species have been collected in the oshanas of which five species are considered to be permanent inhabitants. *Oreochromis mossambicus* is present in the Ondangwa reservoir and individuals may be present in the surrounding waterbodies.

INTRODUCTION

The Cuvelai originates near the Sierra Encoco mountains between the upper reaches of the Kunene and Okavango Rivers (Figure 1). It is not a perennial river as was believed, but permanent waterbodies do exist in the upper reaches (Stengel 1963). The system in Owambo mainly consists of oshanas which are large shallow grassy depressions. The Etosha Pan acts as a sump during heavy summer floods (known locally as efundja) and receives water mainly via the Oshana Ekuma in the north-western side and Oshana Oshigambo in the north-east. A small volume of water is transferred to the pan via Oshana Owambo in the east.

The water flows southwards along the oshanas and into Etosha Pan. The water comes from local precipitation and from the Cuvelai System in Angola, not from the Kunene River as was once believed (Wellington 1955). The first to discover this was Dufour in 1880, but it was only in 1926 that Schedtler and Volkmann conclusively proved this fact (Stengel 1963). The Cuvelai drainage basin is therefore a system separate from the Kunene and Okavango Rivers with its own characteristics and fish fauna (Figure 1).

A canal system became operational in 1972 for the transfer of water from the Calueque Dam on the Kunene River just inside Angola to the interior of Owambo (Figure 2). The Calueque-Olushandja component was put out of action during the late 1970's due to hostilities in the area. It was opened again in 1991. During this period water was pumped from Ruacana. The Calueque-Olushandja component consists of a 3 km pipeline and a 21 km concrete lined canal (Figure 2). The Olushandja Dam has a southern and northern embankment. Water is transferred into the Dam via the concrete canal at the northern embankment. A pipeline exists between

TABLE 1: Descriptions of fish collecting sites in Owambo, February 1991 (See Figure 2).

No.	Collecting site	Substrate	Vegetation	Flow rate	Mean Depth (m)
1	Cuvelai oshana Oshakati	Clay	None	Strong	1,0
2	Cuvelai oshana Oshakati	Clay	Aquatic	Slow	1,5
3	Cuvelai oshana Okatana	Clay	Marginal	Medium	2,0
4	Cuvelai oshana Oshakati	Clay	Aquatic	None	1,5
5	Cuvelai oshana Oshakati	Clay	Aquatic	Slow	1,0
6	Cuvelai oshana Oshakati	Clay	Aquatic	Slow	0,2
7	Cuvelai oshana Oshakati	Clay	Aquatic	None	0,4
8	Earth canal Ombalantu	Clay	Marginal	None	0,5
9	Concrete canal Ombalantu	Cement	None	Strong	1,5
10	Earth canal Oshakati	Clay	Marginal	Medium	0,5
11	Ondangwa reservoir	Sandy	None	None	2,0
12	Oshakati reservoir	Sandy	Marginal	None	3,0
13	Olushandja Dam	Muddy	Aquatic	Slow	1,0

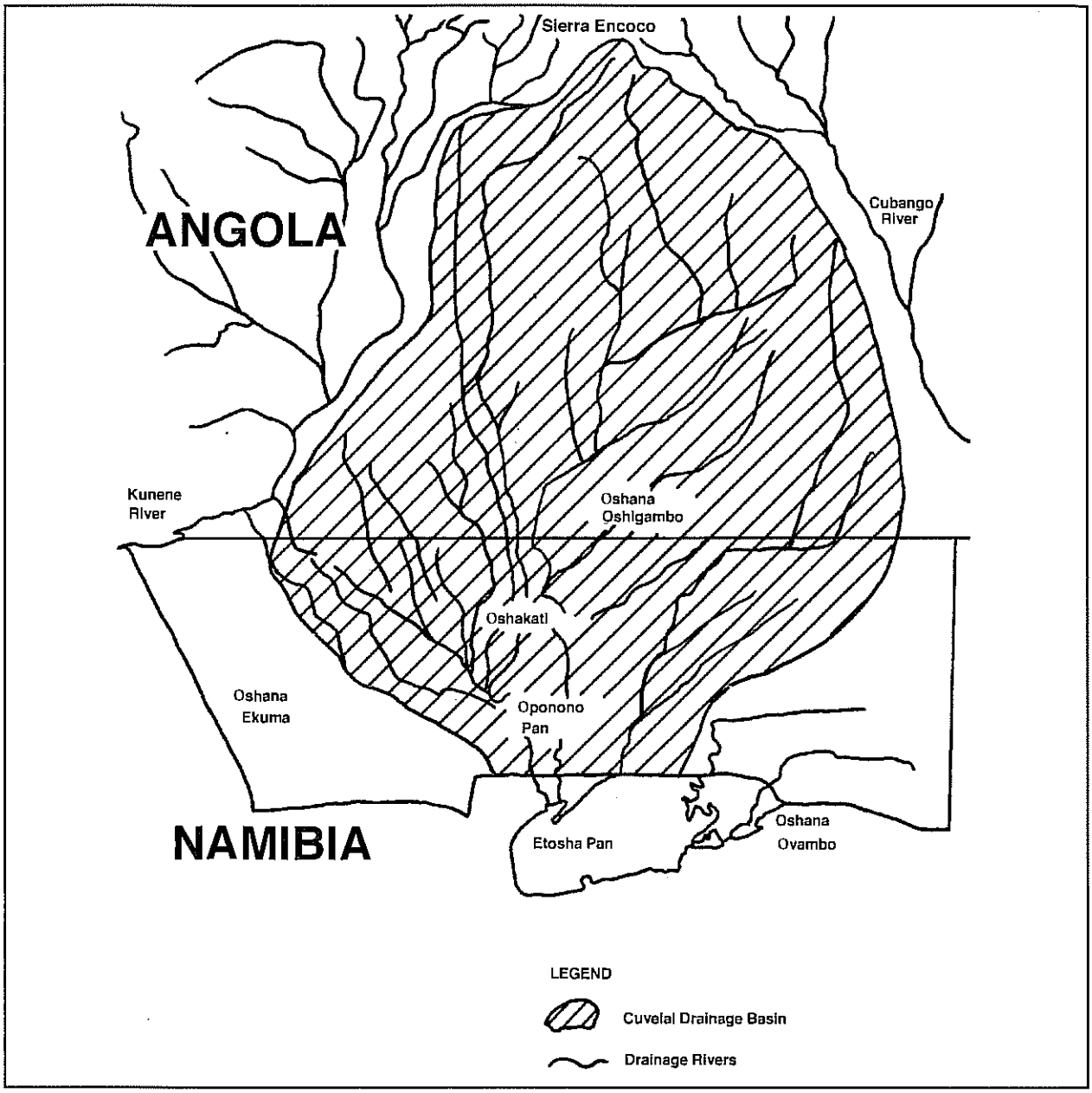

FIGURE 1: The Cuvelai Drainage Basin.

Olushandja and Okahau (60 km) as well as an unlined earth canal (Etaka canal) from the southern embankment of Olushandja Dam. This canal is situated in the Oshana Etaka. The dam provides balancing storage, or is used to release water into the Oshana Etaka. A concrete-lined canal transfers water from Olushandja to the purification works at Ogongo (70 km). Run-off water is collected in an unlined earth canal between Ombalantu and Ogongo. A pipeline transfers water from Ogongo to Oshakati. An unlined earth canal is also present that branches at Oshikuku to Elim. This canal also collects run-off water that supplements the Calueque-Ogongo system. The earth canals were constructed across the oshanas so as to capture water into the canals (Lukowski pers. comm.). These earth canals become flooded when the Cuvelai System flows, and fish species move freely between the oshanas and the canals.

COLLECTING SITES AND EQUIPMENT

Brief descriptions of the collecting sites are listed in Table 1.

The following equipment was used at the collecting sites.
a. A series of gill nets, each 30 m long, with the following stretch mesh sizes: 35, 45, 57, 73, 93, 118 and 150 mm.
b. A 30 m X 1 m seine net with a 12 mm stretch mesh.
c. The fish poison, rotenone.

RESULTS AND DISCUSSION

Water quality and water temperature

The pH in the reservoirs and earth canal was neutral but the Olushandja Dam was slightly acidic (Table 2). The abundance of vegetation in Olushandja Dam is probably the main reason for the low pH and low conductivity. The conductivity and total dissolved solid concentration was slightly higher in the oshanas.

The oshanas and earth canal have a very high turbidity (Table 2). Cyrus (1988) classified a NTU value of 80 as a very high turbidity. Bruton (1988) reported that turbidity reduces egg and larval survival, interferes with

breeding behaviour, reduces food availability, growth rates, habitat diversity and may clog the gill filaments of fish. This will be a major ecological barrier that will determine the species diversity in the oshanas. Tilapia species have a high turbidity tolerance that enable them to be more capable of invasion in turbid systems than less tolerant species (Balarin 1979 ; Philippart & Ruwet 1982).

TABLE 2: Chemical water analysis and water temperature of reservoirs and the Cuvelai oshanas in Owambo, February 1991.

Parameter	Oshakati Reservoir	Ondangwa Reservoir	Olushandja Dam	Cuvelai Oshana	Earth Canal
pH	6,9	6,9	6,3	6,4 - 7,3	6,7 - 7,1
Conductivity mS/m	65,2	34,0	5,8	15,9 - 116,4	21,4 - 22,8
TDS * mg/l	430,0	224,0	38,0	105,0 - 768,0	141,0 - 150,0
Nitrate as N mg/l	< 0,5	< 0,5	< 0,5	< 0,5 - 1,3	< 0,5
Nitrite as N mg/l	< 0,1	< 0,1	< 0,1	< 0,1 - 0,7	< 0,1
Chloride as Cl mg/l	48	24	2	20 - 335	7 - 8
Total Alkalinity mg/l	94	74	28	32 - 128	60 - 102
Turbidity ** NTU	20	0,8	24	120 - 470	160 - 350
Water temperature °C	27	28	30,5	25 - 38	30 - 31,5

* TDS = Dissolved Solids
** NTU = Nephelometric Turbidity Units

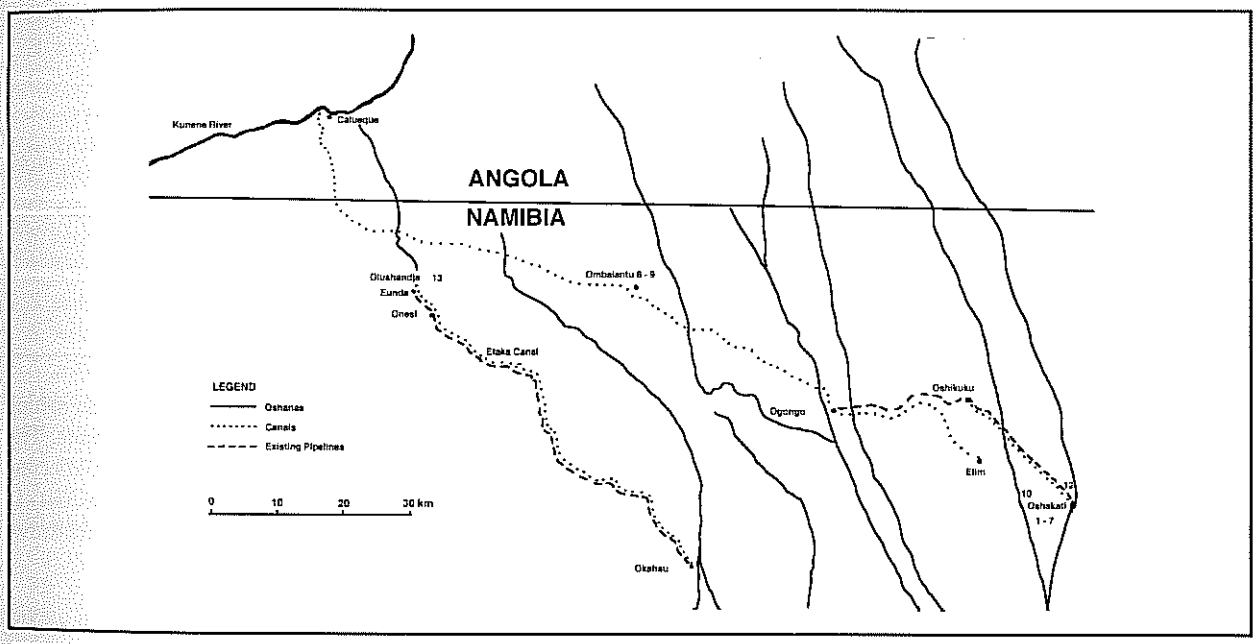

FIGURE 2: The water canal system in Owambo and collecting sites.

Oreochromis macrochir, *Barbus paludinosus* and *Clarias gariepinus* have been collected in the oshanas with temperatures as high as 38°C. The average temperature in the oshanas however is much lower and would not prevent species from entering them. Minimum temperatures do not pose a threat as Owambo has a temperate climate (Van der Merwe 1983). Mean monthly temperatures at Ondangwa vary between 26,1°C in December and 17,5°C in July (Marsh & Seely 1992).

Fish species collected before the building of the canal system.

A total of 13 species had been collected in Owambo before the canal system became operational (Table 3) which were dominated by the families Cyprinidae, Mormyridae, Clariidae and Cichlidae. Species collected were *A. johnstoni*, *B. paludinosus*, *B. mattozi*, *C. gariepinus*, *C. ngamensis*, *M. macrolepidotus*, *M. brevianalis*, *O. andersonii*, *O. macrochir*, *P. castelnaui*, *P. catostoma*, *S. intermedius* and *T. sparrmanii*. *Barbus paludinosus*, *C. gariepinus* and *S. intermedius* were abundant in the Oshana Ekuma while *C. ngamensis* was found to be rare (Bloemhoff 1971). A survey by M. Penrith (unpublished) in Oponono Lake and the Cuvelai System showed that *B. mattozi* and *C. gariepinus* were abundant while *M. macrolepidotus*, *P. catostoma* and *T. sparrmanii* were rare. *Schilbe intermedius* was found to be uncommon (Bloemhoff 1971). *Tilapia sparrmanii* was collected by Penrith mainly on the eastern side of Ondangwa. Several of these species, *A. johnstoni*, *B. mattozi*, *M. macrolepidotus*, *P. castelnaui*, *P. catostoma* and *T. sparrmanii* have never since been collected in the oshanas. Members of the family Mormyridae have also been absent from the oshanas in subsequent surveys and are considered to be present only during large efundjas. The absence of *B. mattozi* is a mystery as Penrith reported it to be abundant in the oshanas prior to the canal system (Bloemhoff 1971). *Barbus mattozi*, *M. macrolepidotus* and *T. sparrmanii* however, seem to have established

viable populations in several reservoirs in Owambo. These species are known for their pool habitat preferences (Gaigher 1969, 1973).

TABLE 3: Fish species collected in oshanas and Oponono Lake in Owambo.

	Present study					
Species	Van der Waal Oponono 1991	Van der Waal oshanas 1991	Oshanas	Earth canal	State Museum Windhoek 1971	Bloemhoff 1971 Oponono, oshanas
M. macrolepidotus					X	X
P. catostoma					X	
P. castelnaui					X	X
M. acutidens		X				
B. barnardi				X		
B. paludinosus	X	X	X	X	X	X
B. poechii/trimaculatus		X	X			
B. bifrenatus		X				
B. radiatus		X				
B. lineomaculatus		X				
B. mattozi						X
M. brevianalis	X				X	
S. intermedius		X			X	X
A. johnstoni					X	
C. gariepinus	X	X	X	X	X	X
C. ngamensis		X				X
P. philander	X	X	X			
O. andersonii	X	X	X	X	X	
O. macrochir			X	X		X
T. rendalli		X		X		
T. sparrmanii						X
Th. buysi				X		

Fish species collected in reservoirs in Owambo

Table 4 lists the species collected in several reservoirs in Owambo that are interconnected with the canal system. Several of these species have established viable populations, including *B. paludinosus*, *C. gariepinus*, *M. brevianalis*, *O. andersonii*, *O. macrochir*, *P. philander* and *T. rendalli*. *Oreochromis andersonii* and *O. macrochir* have not yet invaded the Ondangwa reservoir though both species are present in the Oshakati reservoir. *Barbus paludinosus*, *C. gariepinus*, *M. brevianalis* and *P. philander* have a natural distribution south of the Kunene River in Namibia. *Orthochromis machadoi*, *T. buysi*, *T. albolabris* and *S. coulteri*, which are all endemic to the Kunene River, have also been collected in Owambo. *Coptostomobarbus wittei* is the only species collected in Owambo that has not yet been sampled in the Kunene River, though further collections in the Kunene River may reveal its presence (Hay *et al.* 1995). Several species present in the Kunene River but which are unlikely to disperse to Owambo due to specialised habitat preferences are *B. codringtonii*, *B. eutaenia*, *B. puellus*, *Chiloglanis neumanni* and *Kneria maydelli*. Swamp loving species present in the Kunene River which have the potential to survive in Olushandja Dam are *B. afrovernayi*, *B. thamalakanensis*, *Clarias theodorae*, *C. stappersii*, *P. castelnaui* and *H. multifasciatus* with *P. castelnaui* being collected in Owambo only once. These swamp loving species may increase in diversity and abundance as water is pumped from Calueque which consists mainly of swamp and floodplain habitats. The previous pump station used is situated below the Ruacana Falls in rapid-like habitat. The current species diversity in Owambo may be influenced by these two different draw-off points from the Kunene River.

The greatest species diversity has been found in the Olushandja Dam where 39 species have been collected. This can be attributed to (i) the presence of aquatic vegetation which increases the different habitat types, and (ii) the perennial water conditions resulting from the fact that Olushandja Dam is the first draw-off point from the canal. The species diversity is not constant due to the fluctuation in water level which influences food availability, habitat diversity and protection from predators. *Oreochromis mossambicus* constitutes 47,2% of the total number of fish caught in the Ondangwa reservoirs. The other species present are *B. paludinosus*, *C. gariepinus*, *M. brevianalis*, *P. philander* and *T. rendalli* (Table 4). The presence of *O. mossambicus* is undesirable as interbreeding is possible with the closely related species, *O. andersonii*, which is a permanent resident of the oshanas. Hybrids had been observed in nature by Mortimer (1960) while fertile offspring, all males, were produced in a closed system by Van Zyl (1997). The presence of *O. mossambicus* in Owambo may jeopardise the genetic purity of the cichlids in this region including the Kunene and Okavango Rivers.

TABLE 4: Fish species collected in reservoirs in Owambo.

Species	Van der Waal (1991) Reservoirs	Present study: Olushandja (1991)	Ondangwa Reservoir (1991)	Oshakati Reservoir (1991)
H. ansorgii	X			
M. macrolepidotus	X			X
M. lacerda	X			
P. catostoma	X			
B. lateralis	X			
M. acutidens		X		
R. maunensis	X			
H. odoe	X			
H. machadoi	X			
B.barnardi	X	X		
B. bifrenatus	X			
B. mattozi	X			
B. paludinosus	X	X	X	X
B. poechii / trimaculatus	X			
B. radiatus	X			
B. kerstenii	X			
B. unitaeniatus	X			
C. wittei	X			
M. brevianalis	X	X	X	X
L. ansorgii	X			
C. gariepinus	X	X	X	X
C. ngamensis	X			
S. intermedius	X			
S. leopardinus	X			
S. macrostigma	X			
S. woosnami	X			
A. johnstoni	X			
O. andersonii	X	X		X
O. macrochir	X	X		X
O. mossambicus			X	
T. rendalli	X	X	X	X
T. sparrmanii	X	X		
Or. machadoi	X			
Th. buysi	X	X		
Th. albolabris	X			
Ph. acuticeps	X			
S. codringtonii	X			
S. greenwoodi	X			
S. coulteri	X	X		
S. giardi	X			
S. angusticeps	X	X		
S. macrocephalus	X			X
S. thumbergi	X			
P. philander	X	X	X	

Fish species collected in the oshanas, Oponono Lake and Etosha Pan

The dominant species in the oshanas are *B. paludinosus*, *C. gariepinus*, *O. andersonii*, *O. macrochir* and *P. philander*. These species can be considered as permanent residents and are included in the first order families, being characterised by species encountered where no other fishes occur (Roberts 1975). *Barbus paludinosus*, *B. barnardi*, *C. gariepinus*, *O. andersonii*, *T. rendalli*, and *T. buysi* were present in the earth canal at Ombalantu and Oshakati (Table 3). *Oreochromis macrochir* is listed for the first time as being present in the Cuvelai System. Van der Waal (1991) terms this a late coloniser with specific habitat requirements that is not expected to colonise the Cuvelai System. Philippart and Ruwet (1982) regard this species as a specialised feeder, a characteristic that will probably limit its distribution. Despite these views, *O. macrochir* was found to be common in the oshanas and surrounding waterbodies in Owambo.

Barbus paludinosus and *C. gariepinus* were collected at

all the collecting sites in the oshanas. *Pseudocrenilabrus philander* had a preference for vegetation in stagnant pools while *O. andersonii* was collected in deep pools (1,5 m). *Oreochromis macrochir* had a preference for lotic conditions in the oshanas.

An increase of 32 species are listed for Owambo since the establishment of the canal. *Mormyrus lacerda* and *P. philander* were collected by Pellegrin (1936) at Mupa some 200 km north of Oshakati in Angola, but not in Owambo before the canal system became operational. The invasion of fish and presumably other aquatic species could have been avoided altogether if more thorough surveys and better planning had been done in Owambo before the initiation of the canal system.

Several species already present in the reservoirs have the potential to infiltrate the oshanas during the next major flood. Examples of these species are *B. unitaeniatus*, *M. acutidens M. brevianalis*, *S. leopardinus* and *T. buysi*. Active predators such as *Hepsetus odoe*, *Serranochromis angusticeps* and *S. macrocephalus* are not likely to establish populations due to the high turbidity. The dug - out aquifers hold water for a much longer period of time, which may result in the survival of species in these semi-permanent waterbodies throughout the year.

The earth canal added two species to the list during the 1991 survey namely *B. barnardi* and *T. buysi* (Table 3). *Barbus barnardi* has specialised habitats which will hinder further invasions into the oshanas. *Thoracochromis buysi* was found to be abundant in a variety of habitats in the Kunene River (Hay *et al.* 1995) and together with *T. rendalli* may have the potential to find its way to the upper reaches of the Cuvelai System with the next major flood.

The artificial reservoirs in Owambo are used as a step-off point by several species for the invasion of the Cuvelai System. A major flood event is needed for species to migrate to the head waters of the system where permanent pools exist. It is not possible to determine which of the 46 species listed in Owambo are exotic to the Cuvelai System, except *O. mossambicus*, as very little data is available concerning surveys done in the upper reaches prior to the canal system. A link between the Cuvelai and Kunene Systems in the past is a possibility as *B. mattozi* was collected in the Cuvelai before the canal system became operational. *Barbus mattozi* is present in the Kunene River but is absent from the Okavango River (Cubango in Angola) that is the eastern neighbouring system of the Cuvelai (Figure 1). One of the main factors in the oshanas that limit the species composition is turbidity which in turn will effect the habitat diversity and food availability. The highly seasonal and episodic nature of the Cuvelai System is also likely to affect the species diversity in Owambo.The origin of *O. mossambicus* in the Ondangwa reservoirs is not known but it can be assumed that it was introduced artificially. The nearest population of this species is in the Otjikoto Lake, some 250 km south of Ondangwa, where it is slowly becoming the dominant species. This population had in turn been introduced, probably by local farmers.

The Ondangwa population of *O. mossambicus* is not isolated and it could be present in the surrounding waterbodies. *Oreochromis mossambicus* is very likely to become a permanent member of the fish fauna of the Cuvelai system and, together with *O. andersonii* and *O. macrochir* in this system, the outcome of possible hybridisation is not known.

The dominant families in the oshanas are Cichlidae, Clariidae and Cyprinidae. Specimens of the families Mormyridae and Cyprinodontidae have not been collected in the oshanas since the establishment of the canal system. The reason for this phenomenon is unknown. Characidae is the only family of which specimens were collected in the oshanas that was not present before the establishment of the canal system. This however, is seen only as a temporary invasion.

Van der Waal (1991) reported *T. rendalli* as a species that successfully invaded the oshanas near the canal. However this species was recorded only in the earth canal during the February 1991 survey.

Pseudocrenilabrus philander is the only permanent inhabitant in the oshanas resulting from invasion along the canal system. *Oreochromis macrochir* increased in abundance due to the canal system as it was previously collected only in the Etosha Pan.

The Owambo canal plays a positive role in supplying this area with a valuable protein source that can be utilised by the local people especially during the wet season. The canal system facilitates the transfer of fish into Owambo during the wet season and also ensures the availability of fish in reservoirs during the dry season. The invasion of *O. mossambicus* from the Cuvelai System to the Kunene River is a possibility as the movement of fish in the canal will be difficult to control.

The 1991 survey was done during an average rainy season. The species diversity in the oshanas is expected to increase during high rainfall seasons when efundja events occur, but whether more species will in fact become permanent inhabitants still remains to be seen.

RECOMMENDATIONS

1. The population of *O. mossambicus* in the Ondangwa reservoirs must be destroyed as soon as possible to prevent any genetic pollution in the region. Methods to eliminate the species, are the fish poison, rotenone, seine netting or by draining reservoirs.

2. Fish species not indigenous to either the Kunene or Okavango Rivers should not be kept or released in Owamboland to prevent the dispersal of exotic species from the Cuvelai System to the Kunene and Okavango Rivers.

3. The transfer of species from the Cuvelai System to either the Kunene or Okavango Rivers must be prohibited by all means as the genetic purity of certain species in

Owamboland, especially the cichlids, cannot be guaranteed.

4. Electrophoretic analysis of selected fish species is recommended to determine the taxonomic status of the populations in Owamboland.

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