Fish life of the oshana delta in Owambo, Namibia, and the translocation of Cunene species

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ABSTRACT

The southern end of the endorheic Cuvelai drainage consists of a 130 km wide delta that receives floodwater and migrating fish from the better watered catchment in southern Angola. The fish life of these temporary oshanas is dominated by the genera *Barbus*, *Clarias* and *Oreochromis*, similar to sump lakes of other systems in central and southern Africa. In total, 17 fish species have been recorded from the Cuvelai River. With the construction of a canal, linking the Cunene and Cuvelai systems, 35 Cunene fish species have been collected over a 16 year period in the canal and associated permanent water bodies. Three species have thus far invaded some of the oshanas near the canal. It is expected that with a next major flood many more eurytopic fishes will find their way into the oshanas and eventually to the headwaters of the system.

INTRODUCTION

The oshana delta of central Owambo with a surface area of 7000 km^2 is a unique series of anastomosing temporary shallow channels of the Cuvelai River of southern Angola. In years of normal rainfall (500 mm: Lempp 1963; Stengel 1963) these shallow depressions fill with rainwater for a period of two to four months. In years with above average rain, water from the upper part of the catchment in Angola drains slowly southwards bringing with it young fish that are then eagerly collected by both the Owambo people and birds (Stengel 1963; Berry et al. 1973; Van der Waal 1988). No organised survey of the fish life of the oshanas ever seems to have been undertaken. References to fish species collected in Owambo were made by Berry et al. (1973), Dixon & Blom (1974) and M. J. Penrith (pers. comm.). During short visits to the area between 1975-1989, I made several collections that are included in this paper.

The central part of Owamboland is heavily populated with more than 300 000 people (Claasen & Page 1978) and the temporary open water and infrequent fish resources of the oshanas play an important role for these rural populations (Barnard 1967). Presently, most of the people are not dependent on oshanas for water because a canal system, and later a pipeline, was built to bring water from the Cunene River (Anon 1967). These structures have also affected the fish life of the oshanas. Preliminary observations on the transfer of Cunene species via the canal, reported by Van der Waal (1984), Schrader (1985), and De Moor & Bruton (1988), are further investigated in this paper.

METHODS

The fishes in oshanas and permanent man-made water bodies were studied during short visits to the area in October 1975, March/April 1976, May/June 1977, April 1979, December 1984, December 1986, December 1988 and November 1989. Collections were made using bagged seine nets 90 and 14 m long with 20 and 10 mm stretched mesh respectively, a fleet of gill nets with mesh sizes of 25, 50, 100, 127, 155 and 190 mm, a large dip net fitted with 10 mm stretched mesh, explosives and by angling. Samples were also received from local fishermen who used a variety of traditional and modern apparatus, including small mesh seine nets. Fish were collected at the following localities:

1. Hinakulu Yomadhiya ("mother of the pans"), shown as Oponono Pan on maps, origin of the Ekuma River (18°10'S 15°50'E). Oponono is a complex of large semipermanent shallow pans of 5-500 ha in surface area, some with submerged and emergent aquatic vegetation. Seine nets were used to collect fish and the catch of fishermen was also inspected. Collections were made in 1975, 1984 and 1989.

2. Running oshanas between Oshakati (17°46'S, 15°42'E) and Ondangwa (17°53'S, 15°58'E) and at Oshikuku (17°39'S, 15°29'E). Seine and dip nets were used to collect fish in April 1976. Water was flowing strongly (0,25 m sec^{-1}) and the oshanas were well vegetated with submerged plants: *Nymphaea caerulea*, *Ottellia exerta*, *Potamogeton crispus*, *Utricularia* spp. as well as emergent aquatic grasses, *Ipomoea* sp. and *Mimosa* sp. Catches of fishermen using a variety of apparatus were also inspected. Oshanas with standing water were also sampled in 1975 and 1984.

3. Olushandja Dam, situated in Oshana Etaka (17°25'S, 14°40'E). Between 1972-1985, water from the Cunene River at Calueque (17°16'S, 14°34'E) or Ruacana (17°23'S, 14°12'E) was pumped intermittently into the shallow wooded reservoir (2700 ha at full capacity) from where water was gravitated to Ogandjera and Ogongo (17°40'S,15°18'E), and after settling and purification, piped to major centres in Owambo. Fish were collected using a series of gill nets, a small mesh seine net and a 90 m long, 5 m deep seine with 20 mm stretched meshes. Fish were also collected by angling with artificial lures, use of explosives in weedy areas and by purchase from local fishermen. Collections were made in 1977, 1979, 1984 and 1986.

4. Owambo canal and connected reservoirs at the following localities: inlet of Olushandja Dam, canal and ponds at Mahanene Agricultural Research Station, Ombalantu, Ogongo, and reservoirs of the Department of Water Affairs at Oshakati and Ondangwa that receive pumped water from the original earthen canal. Gill nets and a small seine were used to collect fish. Collections were made in 1977, 1979, 1984, 1986 and 1988.

5. Cunene River at Calueque and Ruacana. Gill and seine nets and explosives were used to collect fish species. At Calueque in 1984, fish were collected above the barrage near the pipeline intake. These included well vegetated areas with submerged and emergent vegetation and below the barrage in the strongly flowing current. At Ruacana, collections were made in 1986 in pools and in the river itself below the waterfall just downstream of the intake of the pipeline.

Water samples were collected and analysed by the Department of Water Affairs, Windhoek, and analysed according to stan-

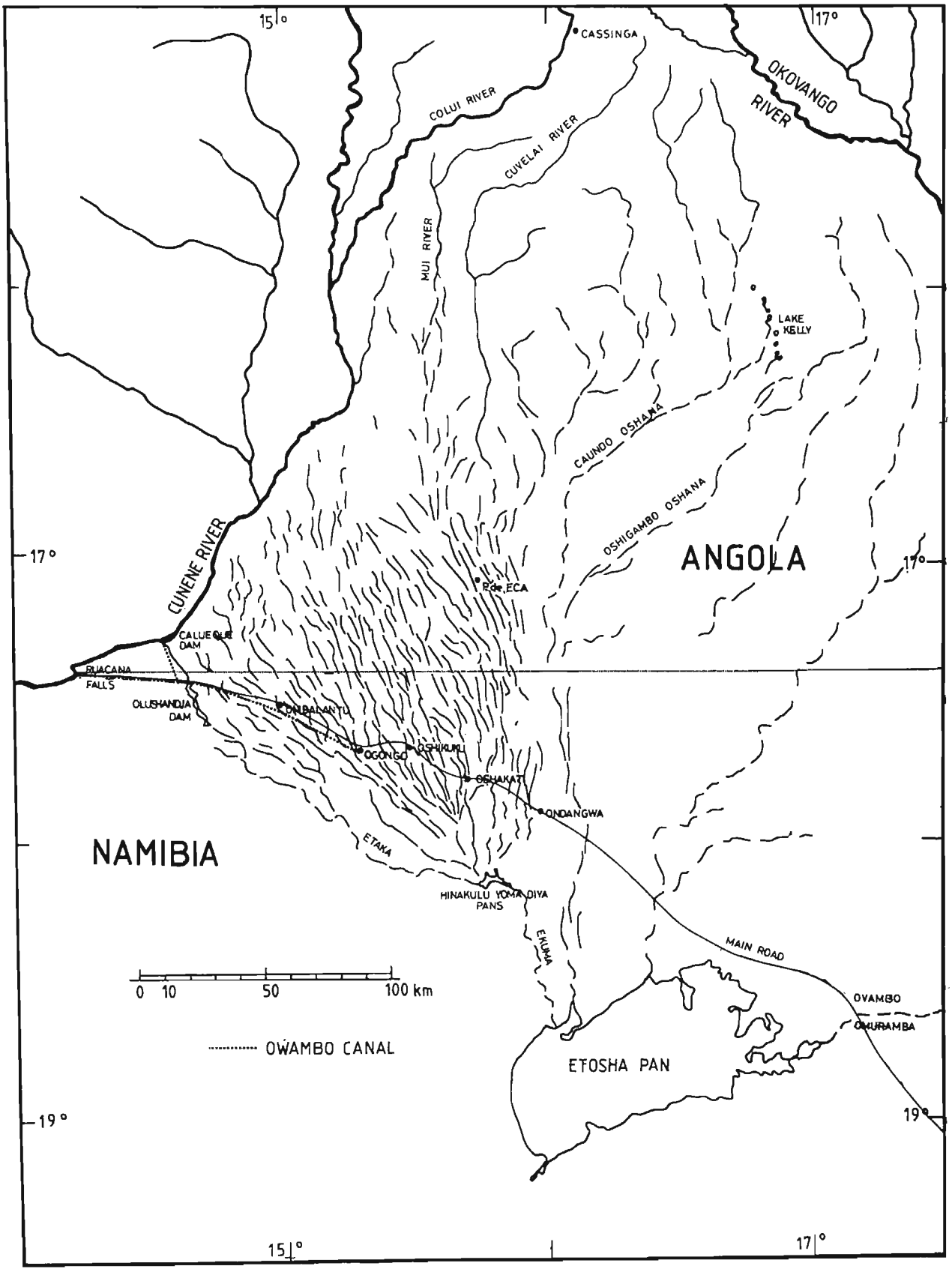

FIGURE 1: Map of the Cuvelai Drainage in Angola and Namibia indicating man-made connections with the Cunene River.

dard procedures in their laboratories.

HYDROLOGY AND MAN-MADE AQUIFERS

The Cuvalai drainage with its main branches, the Mui and Caundu (Fig. 1), lies wedged between the Cunene and the Kavango Rivers and covers an area of 37 200 km² (Stengel 1963). It is a relict endorheic system, draining infrequently into the Etosha Pan. River capture by the present-day Cunene probably took place during the Pliocene, and the site of river capture is marked by the Olushandja oshana entering the Cunene above a series of rapids and falls at Calueque (Wellington 1938, 1955; Mackenzie 1946; Bell-Cross 1968; Jubb 1967; Berry et al. 1973).

The Cuvelai River originates 260 km north of the Angolan border at an altitude of 1450 m in an area with an annual rainfall of more than 1000 mm where the source streams are well defined and permanent (Stengel 1963; Barnard 1967; M.J. Penrith, pers. comm.). About 100 km north of the border the river enters a flat, featureless sandy plain and diverges to form a delta of anastomosing oshanas where the slope decreases and the precipitation drops to less than 500 mm (Table 1). The oshana complex consists of an anastomosis of 100-500 m wide shallow (30-100 cm) drainage channels through a flat, sandy, tree-covered country. The southern half of the oshana district of 14 000 km² lies in central Owambo. The Cuvelai River itself branches repeatedly and feeds the eastern half of the oshanas, while the western section (west of Ogongo) is indirectly linked in years of above average rainfall and runs only after heavy rain in the territory north of Ombalantu (Fig. 1).

TABLE 1: Elevations, gradients and annual rainfall in the Cuvelai drainage.

Locality	Km north of Etosha	Elevation m asl	Gradient	Rainfall mm per year
Cassinga	400	1456		1095*
Mupa	280	1178	1:719	833*
Ongiva (P de Eca)	180	1104	1:1 350	848*
Ondangwa	85	1096	1:11 900)	496***
Oponono	60	1085	1:2 700	
Etosha Pan	0	1081	1:15 000	430**

* data from Stengel (1963)
** data from Berry (1972)
***data from Barnard (1967)

In Owambo all the oshanas converge into the westernmost oshana Etaka which drains into a series of shallow (100-400 cm deep) semipermanent lakes: Hinakulu Yomadhiya, Etuntu, Uhulidi, Nyakuru and Oponono (maps show Oponono Pan which is mostly dry and lies most westerly). The well defined oshana Ekuma (Plate 3) drains flood water finally southwards to Etosha Pan where all water evaporates (Berry 1972). Drainage channels west of the Cuvelai River such as oshana Oshigambo and omuramba Ovambo drain separately in the north and east of Etosha (Berry 1972). To the west and east of the central oshana delta lie stretches with no clear drainage systems. This includes the so-called "panneljiesveld", an area of small isolated pans as large as the oshana district itself.

Oshanas start filling with rainwater early in the rainy season, usually December. Floodwater from Angola reaches Owambo by February (extremes January-April) and oshanas usually stop running by May (extremes April-June, data of seven seasons, Stengel 1963; D. J. Plathe, pers. comm.) and are usually completely dry by July-August.

It was popularly believed that the origin of floodwater in the oshanas (termed *efundja* in Ndonga) as well as the seasonal fish life, originated from the flooding Cunene River (Nitzsche 1913; Kanthack 1921; Du Toit 1926; Lempp 1961). This idea was promoted by those in favour of the proposed Kalahari Lake Scheme which intended to create a huge inland lake by restoring previous drainages, including the ancient Cunene southwards into Etosha Pan (Schwartz 1920). Only after detailed survey work by Schedtler and Volkman (Stengel 1963) and E. Hudson Spence (Wellington 1938; Mackenzie 1946; Barnard 1967), was it established that the Cuvelai is a completely separate drainage system. Table 2 presents data on the frequency of floods (efundja) as recorded by Stengel (1963) and from personal observations together with rainfall figures. The unreliability and unpredictability of both rainfall and floods prompted the construction of the present water supply systems in Owambo (Lempp 1961; Barnard 1967; Anon 1975).

TABLE 2: Frequency of *efundja* floods in Owambo from 1941-1961 (Stengel 1963) and 1975-1990 with rainfall data for Oshakati.

Year	Extent of efundja				Rainfall
	None	Small	Medium	Large	mm
1941/2		X			507
1942/3		X			800
1943/4			X		893
1944/5		X			507
1945/6	X				261
1946/7			X		837
1947/8		X			544
1948/9	X				589
1949/50			X		972
1950/1		X			686
1951/2	X				399
1952/3	X				327
1953/4				X	600
1954/5	X				254
1955/6			X		533
1956/7				X	442
1957/8	X				507
1958/9		X			293
1959/60	X				418
1960/1			X		378
1975/6		X<			637*
1976/7				X	716*
1977/8	X				365*
1978/9		X<			612*
1979/80	X				469*
1980/1	X				424*
1981/2		X			327*
1982/3		X<			363*
1983/4		X			334*
1984/5		X<			587*
1985/6	X				465*
1986/7		X<			505*
1987/8	X				275*
1988/9	X				148*
1989/90		X			-

< no fish, efundja in westerly oshanas only
* Dept of Water Affairs, Oshakati, F Binneman, pers. comm.

The first canal was started in 1959 by connecting all the oshanas between Ombalantu (17° 30'S, 14° 59'E) and Ondangwa (Lempp 1961). Flood water from the oshanas was thus intercepted and channelled to centers where it was pumped into deep reservoirs. In 1970 the Owambo canal was initiated and from 1972 water was pumped from a barrage in the Cunene River at Calueque up to the watershed near Olushandja Dam, from where it was gravitated by an unlined canal with a slope of 1:15 000 to as far as Oshakati. This canal was also interconnected with all oshanas

along the way (Anon 1975). The canal was replaced in 1975 by a proper lined canal to Ogongo from where purified water was distributed to the major centers (Ravenscroft 1984). This canal has direct connections with oshanas only at Ogongo and Olushandja Dam. The dam was originally built for balancing purposes but as result of its shallow nature and high evaporation rates, has not been filled since 1984. The additional pump and pipeline from Ruacana to Olushandja Dam was used regularly since 1980 to replace the damaged facilities at Calueque during the escalation of the war on the border with Angola.

RESULTS AND DISCUSSION

Fish species of the oshanas

Table 3 summarizes the fish collections made in oshanas of Owambo between 1975 and 1989. Additionally, previous collections by Pellegrin (1936), the State Museum, Windhoek and Berry et al. (1973) are tabled. All my identifications were verified by Dr P.H. Skelton (J.L.B. Smith Institute of Ichthyology) or Mr J.A. Cambray (Albany Museum) and collected material is housed at these institutions. A list of all the fish species recorded from the Cuvelai and Cunene Rivers is presented in Table 4.

TABLE 3: Fish species collected in oshanas in Owambo and Cuvelai in Angola (Pellegrin 1936, indicated as O).

	Locality and date									
FISH SPECIES	Etosha Pan, February 1968 (State Museum, Windhoek = SMW)	Etosha Pan & Lake Oponono April 1971 (Berry *et al.* 1973)	Hinakulu Yomadiya (Oponono) October 1975	Hinakulu Yomadiya (Oponono) December 1984	Hinakulu Yomadiya (Oponono) November 1989	Oshanas, Oshakati, 1966 - 1968 (SMW) & 0 = Mupa, 1928 - 1933 (Pellegrin 1936)	Oshanas, Ondangwa & Oshikuku October 1975	Running oshanas, Oshakati March-April 1976	Oshanas, Ondangwa December 1984	Oshanas connected with canal Oshakati, December 1984
M. macrolepidotus	-	-	-	-	-	X+0	-	-	-	-
M. lacerda	-	-	-	-	-	0	-	-	-	-
P. castelnaui	-	-	-	-	-	X	-	-	-	-
P. catostoma	-	X	-	-	-	X	-	-	-	-
M. acutidens	-	-	-	-	-	-	-	X	-	-
B. bifrenatus	-	-	-	-	-	-	-	X	-	-
B. paludinosus	-	X	X	X	X	X+0	X	X	X	X
B. poechii/trimaculatus	-	-	-	-	-	-	-	X	-	X
B. radiatus	-	-	-	-	-	-	-	X	-	-
M. brevianalis	-	-	-	-		X	-	-	-	-
C. garjepinus	X	X	X	X	X	X	X	X	X	X
C. ngamensis	-	X	X	X	X	-	X	X	-	-
S. mystus	X	X	-	-	-	X	-	X	-	-
A. johnstonii	-	-	-	-	-	X	-	-	-	-
O. andersonii	X	-	X	X	X	-	-	X	X	X
T. rendalli	-	-	-	X	-	-	-	-	-	X
T. sparrmanii	-	-	-	-	-	0	-	-	-	-
S. coulteri	-	-	-	X	-	-	-	-	-	-
P. philander	-	-	X	X	X	0	X	X	-	X

TABLE 4: Fish species collected in Owambo and the Cunene River and additionally recorded from the Cunene River (*).

Fish species	Standard name
Mormyridae	
1 Hippopotamyrus ansorgii	slender stonebasher
2 Marcusenius macrolepidotus	bulldog
* *(=Gnathonemus angolensis)*	
3 Mormyrus lacerda	western bottlenose
4 Petrocephalus catostoma	churchill
5 Pollimyrus castelnaui	dwarf stonebasher
* *(=Hippopotamyrus pappenheimi?)*	
Kneriidae	
*6 *Kneria angolensis*	kneria
*7 *Kneria maydellii*	Maydell's kneria
Characidae	
8 Brycinus lateralis	striped robber
* *(=B. humilis)*	
9 Micralestes acutidens	silver robber
* *(=M. agryrotaenia?)*	
10 Rhabdalestes maunesis	Okavango robber
* *(=Petersius woosnami)*	
Hepsetidae	
11 Hepsetus odoe	African pike
Citharinidae	
12 Hemigrammocharax machadoi	dwarf citharine
* *(=H. monardi)*	
13 Hemigrammochrarax multifasciatus	multibar citharine
* *(=N. fasciolaris)*	
Cyprinidae	
*13 *Barbus afrovernayi*	spottail barb
14 Barbus barnardi	blackback barb
* *(=B. lujae)*	
15 Barbus bifrenatus	hyphen barb
* *(=B. viviparus)*	
*16 *Barbus codringtonii*	Upper Zambezi yellowfish
*17 *Barbus dorsolineatus*	
*18 *Barbus eutaenia*	orange fin barb
19 Barbus fasciolatus	red barb
* *(=B. barilioides)*	
*20 *Barbus kerstenii*	redspot barb
* *(=B. kessleri)*	
21 Barbus lineomaculatus	line-spotted barb
22 Barbus mattozi	papermouth
* *(=B. argenteus?)*	
23 Barbus paludinosus	straightfin barb
24 Barbus poechii	dashtail barb
* *(=B. trimaculatus?)*	threespot barb
*25 *Barbus puellus*	dwarf barb
26 Barbus radiatus	Beira barb
* *(=B. aurantiacus)*	
27 Barbus tangandensis	redspot barb
28 Barbus thamalakanensis	Thamalakanane barb
29 Barbus unitaeniatus	longbeard barb
* *(=B. inermoides)*	
30 Coptostomabarbus wittei	upjaw barb
31 Mesobola brevianalis	river sardine
32 Labeo cylindricus	redeye labeo
* *(=L. ansorgii)*	
33 Labeo molybdinus	leadfish
34 Labeo ruddi	silver labeo
Bagridae	
*35 *Zaireichthys* sp. (cf *cunenensis*)	cunene sand catlet
Clariidae	
*36 *Clarias (= liocephalus)*	smoothhead catfish
37 Clarias gariepinus	sharptooth catfish
38 Clarias ngamensis	blunttooth catfish
33 Clarias theodorae	snake catfish
40 Clarias stappersii	blotched catfish
Schilbeidae	
41 Schilbe mystus	silver catfish
Mochokidae	
42 Synodontis leopardinus	leopard squeaker
43 Synodontis macrostigma	largespot squeaker
44 Synodontis woosnami	Upper Zambezi squeaker
45 Synodontis sp. nov. 1	
46 Synodontis sp. nov. 2	
*47 *Chiloglanis neumanni*	Neumann's rock catlet
Poeciliidae	
48 Aplocheilichthys johnstonii	Johnston's topminnow
*49 *Aplocheilichthys katangae*	striped topminnow
50 Aplocheilichthys macrurus	Angolan topminnow
Cichlidae	
51 Oreochromis andersonii	threespot tilapia
52 Oreochromis macrochir	green tilapia

TABLE 4 continued

53 *Oreochromis mossambicus*	Mozambique tilapia
54 *Tilapia rendalli rendalli*	northern redbreast tilapia
55 *Tilapia sparrmanii*	banded tilapia
56 *Orthochromis machadoi*	Cunene dwarf happy
57 *Thoracochromis albolabris*	thicklipped happy
58 *Thoracochromis buysi*	Namib happy
59 *Pharynchochromis darlingi(?)*	Zambezi happy
60 *Serranochromis(Sargochromis) codringtoni*	green happy
61 *Serranochromis(Sargochromis) coulteri* * *(=S. angolensis)*	Cunene happy
62 *Serranochromis (Sargochromis) giardi*	pink happy
63 *Serranochromis(Sargochromis) greenwoodi*	Greenwood's happy
64 *Serranochromis(Serranochromis) angusticeps*	thinface largemouth
65 *Serranochromis(Serranochromis) macrocephalus*	purpleface largemouth
66 **Serranochromis(Serranochromis) robustus jallae*	
67 *Serranochromis(Serranochromis) thumbergi*	brownspot largemouth
68 *Pseudocrenilabrus philander*	southern mouthbroooder

* P H Skelton (*in litt.*) based on Ladiges & Voelker 1961, Ladiges 1964, Jubb 1967, Poll 1967, Bell-Cross 1982, Greenwood 1984 and collection in the State Museum, Windhoek.

The following fish comunity was found in running oshanas : *Micralestes acutidens, Barbus bifrenatus, B. paludinosus, Barbus poechii/trimaculatus**, *B. radiatus*, *Clarias gariepinus*, *C. ngamensis*, *Schilbe mystus*, *Oreochromis andersonii* and *Pseudocrenilabrus philander*. Additionally, *Marcusenius macrolepidotus*, *Petrocephalus catostoma*, *Pollimyrus castelnaui*, *Mesobola brevianalis* and *Aplocheilichthys johnstonii* had been collected earlier by other workers in oshanas in Owambo (H Berger-Dell'mour pers. comm., J.A. Cambray pers. comm., P.H. Skelton pers. comm.). Pellegrin (1936) recorded *Mormyrus lacerda* and *Tilapia sparrmanii* from the Culevai River at Mupa, some 200 km north of Oshakati. Most of these species have not been collected in oshanas since 1976 (Table 3) and must presently be considered as irregular migrants in the oshanas. The absence of any major floods during the study period apart from 1976 may have played a role in preventing the southward migration of the less common fish species. It must be assumed that *Barbus poechii/trimaculatus*, *B. bifrenatus* and *B. radiatus* already had escaped into the oshanas from the canal before 1976 as they all were present in Olushandja Dam in 1977 but never collected in the Cuvelai system before the construction of the canal (Tables 3 & 8). The only means by which fish could have gained access to the dam was through the supplying pipeline from the Cunene River.

All the species collected in the oshanas also occur in the Cunene and Okavango systems (Bell-Cross 1967; Jubb 1967; Gaigher & Jubb 1971; Skelton et al. 1985). In the Cunene River above Ruacana or in the canal, 42 further species were collected during the present surveys and 13 species are additionally recorded from the upper Cunene by Ladiges (1964), Bell-Cross (1982) and P. H. Skelton (pers. comm.).

The Okavango, which may have had connections with the Cuvelai (Skelton et al. 1985), is inhabited by at least 80 species. The fish community of the oshanas can then be seen as impoverished if compared to that of the Cunene from which it may have originated. Table 3 shows that the Oponono Pan with seven species and Etosha Pan with only five species, harbour even less fish than the oshanas, indicating unfavourable and variable conditions, due to the high conductivities and extreme salinities recorded in Oponono Pan (Table 5). All the species collected in Etosha Pan are considered to be eurytopic with the possible exception of the mormyrids that were collected only once after exceptional flooding, before salinities increased (Berry et al. 1973). The situation in the oshanas and particularly Oponono and Etosha Pans can thus be compared to the sump lakes in the Okavango Swamps (Gaigher & Jubb 1971; Skelton et al. 1985), distal pools in the Zambezi floodplain (Van der Waal & Skelton 1984), Lake Chilwa, Malawi (Kalk 1968) and floodplain pans of the Pongolo River, Zululand (Jackson 1989). The species there are to some extent euryhaline, hardy, generalist feeders, and are either prolific spawners or exhibit parental care with flexible life styles. The dominant position of *B. paludinosus*, *Clarias* spp. and *O. andersonii* in the oshanas and sump lakes follows the typical pattern for endorheic lakes recorded in southern Africa (Jackson 1989).

*specimens with one oblong dash on the peduncle (typical of *B. poechii*), with three distinct lateral spots (*B. trimaculatus*), and all possible intermediate forms were collected. The status of these two species should be further examined (Greenwood 1962).

TABLE 5: Water quality of oshanas and Hinakulu Yomadhiya (Oponono Pan). Data from Department of Water Affairs, Windhoek.

Locality	Date	pH	Conductivity mS cm^{-1}	mg l^{-1} Cl$^-$	Na$^+$	Alkalinity mg $CaCO_3$ l^{-1}
Oshakati, Cuvelai	22/4/'76	6.7	26	2	2	26
Oshakati, Cuvelai	22/4/'76	6.6	390	78	60	30
Oshakati, Cuvelai	28/4/'76	7.3	55	6	6	24
Oshakati, Oshana	6/5/'77	7.5	499	45	46	50
Ombalantu, Oshana	6/5/'77	8.4	342	25	20	85
Oshikuku, Oshana	6/5/'77	8.1	468	25	49	95
Ongediva, Oshana	6/10/'72	8.4	705	65	83	65
Oponono *	15/10/'75	7.2	14 500	4 700	3 860	375
Oponono, inlet	15/10/'75	8.8	43 000	15 650	13 268	1 160
Oponono	7/8/'75	5.8	3 375	1 060	825	40
Oponono	9/12/'75	8.5	47 500	13 350	12 050	1 050

* Fish were collected here in 1975

Structure and size of fish populations in running oshanas

Table 6 presents data on numbers and lengths of fish from the oshana Cuvelai collected by Owambo fishermen using 10 mm mesh fyke nets (2-5 m wide and 6-15 m long), set across the running oshana and intercepting fish migrating downstream. The fish community was dominated by subadults of small barbs, and juveniles of the larger *Clarias gariepinus*, *C. ngamensis*, *Schilbe mystus* and *Oreochromis andersonii* (Table 3). In other oshanas the observed catches were dominated by *B. paludinosus*, followed by *C. gariepinus*, *B. poechii/trimaculatus*, *C. ngamensis*, *S. mystus*, *O. andersonii* and *P. philander*.

TABLE 6: Composition of fyke net cathes in running oshanas, April 1976

FISH SPECIES	Fyke net 1	Fyke net 2	Fyke net 3	Mean length mm	(min-max)
M. acutidens	-	-	1	-	
B. poechii/trimaculatus	-	9	231	75	(30-90)
B. paludinosus	50	27	1980	50	(25-70)
B. bifrenatus	-	-	1	-	
B. radiatus	-	2	990	-	
C. gariepinus	1	15	56	300	(144-490)
C. ngamensis	1	-	2	180	(100-230)
S. mystus	-	16	33	110	(73-140)
O. andersonii	-	-	1	70	
P. philander	-	22	1	-	

As the whole oshana system dries up completely annually (Lempp 1961; Stengel 1963), all these fish must have migrated from the more permanent regions of the Cuvelai, 200 km further northwards, after the rains started to fill the rivers and oshanas in January-February (Fig. 1). Even where man-made excavations and wells in oshanas might have acted as refugia, it would not contain any fish by the next rainy season because of continuous fishing activities in the densely populated oshana district. All fish collected in oshanas were inspected for gonadal development and found to be immature, with the exception of *P. philander*. They must have been young of the year that participated in a massive (re)colonising migration downstream into the temporary extension of the river system. The recorded lengths suggest high growth rates of these migrating fish down the shallow, newly inundated, warm and productive oshanas (Table 6). The predatory *C. gariepinus* had reached a length of up to 490 mm after only 3-4 months. The related *C. ngamensis*, however, showed a comparatively slower growth rate (100-230 mm), possibly because its preferred food, molluscs, were not as plentiful as fish (mainly *Barbus* spp.), the dominant prey item in *C. gariepinus* stomachs.

TABLE 7: Fish catches of fishermen along the Oshakati-Ondangwa road, 29 March 1976.

Equipment	Number of fishermen	Mean catch per day kg
funnel nets	25	150
fishing rods	88	3
dip nets	10	10

Opportunities to estimate population densities in the running oshanas were not available but a survey of catches of fishermen along the main road between Oshakati and Ondangwa was made (Table 7). A total of 4200 kg of fish was collected at the culverts of seven oshanas in one day. With an efundja flood of 60 days this represents 250 000 kg along this road alone. In comparison, Berry et al. (1973) estimate the crop of fish removed by breeding pelicans from the Oponono (Hinakulu Yomadhiya) Pan alone during the 1969 efundja flood, at 975 000 kg. There is therefore, every indication of considerable fish biomass in the running oshanas.

Invasion of Cunene species into the oshana system

As a result of the unreliability of regular efundja floods (Table 1), the availability of surface water has always been a limiting factor in the development of Owambo (Lemp 1961; Barnard 1967). The pumping scheme at Calueque became functional in 1972 when water from the Cunene was pumped into the Owambo Canal (Anon 1975; F. Binneman pers. comm.). Results of collections in the canal itself and the large balancing reservoir, Olushandja Dam, as well as reservoirs and silt trap dams at the end of the canal system, are summarized inTable 8. In total 34 fish species were collected, most of which were previously unknown to the local inhabitants. These fish had gained access to the canal and associated water bodies after successful passage through the turbine pumps (Jubb 1976).

Apart from the 34 Cunene species found in the canal and Olushandja Dam, the following species were also collected in Olushandja Dam and canal in 1977 - 1984: *M. macrolepidotus, M. lacerda, P. catostoma, B. paludinosus, M. brevianalis, C. gariepinus, C. ngamensis, S. mystus, A. johnstoni, O. andersonii, T. sparrmanii* and *P. philander*. As Olushandja Dam has no catchment at all and receives only piped water from the Cunene, the fish species collected in the dam must be translocated Cunene species. There were many opportunities for these fish to mix with the original Cuvelai fishes, especially before the construction of the lined canal. It is thus likely that the original Cuvelai populations of these 12 fish species are no longer genetically pure and the total number of Cunene species that have been transferred to Owambo totals 46.

The extent of contact between the "inocula" in the upper reaches of the system and the populations of the temporary oshanas by means of upstream migration is not known. Upstream migrations of young fishes that had hatched in Owambo (Hinakulu

TABLE 8: Fish species collected in oshanas, the Owambo canal, associated reservoirs and the Cunene River.

Locality and date / Fish species	Previous collections in oshanas, 1966-1975	Running oshanas, 1976	Olushandja Dam 1977,1979	Oshanas, 1984	Olushandja Dam, 1984	Ogongo sump pond, 1984	Oshakati reservoir, 1984	Olushandja Dam, 1986	Mahanene sump pond, 1986	Ogongo sump pond, 1986	Oshakati sump pond, 1986	Ombalantu sump pond, 1988	Cunene River, 1984,1986
H. ansorgii			X										X
M. macrolepidotus	X		X		X	X		X	X			X	X
M. lacerda									X				X
P. catostoma	X		X										X
P. castelnaui	X												X
B. lateralis			X		X	X	X		X	X	X		X
M. acutidens		X							X	X			X
R. maunensis			X		X								
H. odoë									X				X
H. multifasciatus													X
H. machadoi			X										X
B. barnardi			X						X	X			X
B. bifrenatus		X	X										X
B. fasciolatus													X
B. lineomaculatus													X
B. mattozi			X			X		X	X			X	X
B. paludinosus	X	X	X	X		X	X	X	X	X			X
B. poechiltrimaculatus		X	X	X	X	X	X		X	X		X	X
B. radiatus		X	X		X	X	X						X
B. tangandensis			X										X
B. thamalakanensis													X
B. unitaeniatus					X	X				X		X	X
C. wittei			X										
M. brevianalis	X		X			X				X			X
L. cylindricus			X						X				X
L. molybdinus			X		X	X		X		X			X
L. ruddi													X
C. gariepinus	X	X	X	X	X	X	X	X		X	X	X	X
C. ngamensis	X	X	X		X	X	X	X		X	X	X	X
C. stappersii													X
C. theodorae													X
S. mystus	X	X	X					X					X
S. leopardinus			X			X		X	X				X
S. macrostigma			X			X		X	X				X
S. woosnami			X						X				X
S. sp. nov 1									X				X
S. sp. nov 2									X				X
A. johnstonii	X				X			X					X
A. macrurus													X
O. andersonii	X	X	X	X	X	X	X	X	X	X	X	X	X
O. macrochir								X	X	X		X	X
T. r. rendalli			X	X	X	X	X	X	X	X	X	X	X
T. sparrmanii			X		X	X	X	X		X			X
Or. machadoi					X				X				X
Th. alholabris									X	X			X
Th. buysi			X		X	X							X
Ph. darlingi			X			X		X	X			X	X
S. (Sarg.) codringtoni			X							X		X	X
S. (Sarg.) coulteri			X		X	X		X		X			X
S. (Sarg.) giardi			X		X					X			
S. (Sarg.) greenwoodi							X					X	X
S. (S.) angusticeps					X								X
S. (S.) macrocephalus			X		X	X	X	X	X	X	X	X	X
S. (S.) thumbergi			X										
P. philander	X	X	X	X	X	X		X	X	X	X		X
Number of species	11	10	34	6	20	21	11	18	23	20	7	13	51

Yomadiya pans) is a possibility. During the 1976 survey, a limited upstream migration of *B. paludinosus* (30-50 mm) and *O. andersonii* (50-70 mm) was observed in the oshana Cuvelai. These fish were smaller than the fishes collected in nets intercepting the major downstream migration. At Oshikuku, *B. poechii/trimaculatus, B. paludinosus* and young *C. gariepinus* were observed jumping out of the earthen canal into the overflowing Oshikuku oshana.

The spread of *T. rendalli, S. coulteri* and *S. macrocephalus* present examples of limited colonisation of the oshana system. They were recorded in 1977 in Olushandja Dam and had reached reservoirs connected to the canal at Ogongo and Oshakati and even Hinakulu Yomadhiya pans by 1984. These fish species are most likely to reach the permanent upper reaches of the system and to become a permanent component of the fish community. Many other fish species do not seem to possess the ability to survive or maintain themselves in the canal and smaller associated water bodies. Of the 34 Cunene species recorded in Olushandja Dam in 1977 with its fertile, weedy, newly flooded conditions, only 20 were still present by 1984. Water levels had then dropped and predation pressure (by many piscivorous birds) and competition had increased.

It is possible to group the fish species that have entered Owambo via the canal provisionally into the following categories:

1. Early invaders
M. macrolepidotus, B. lateralis, B. paludinosus, B. poechii/trimaculatus, B. radiatus, C. gariepinus, C. ngamensis, S. andersonii, T. rendalli, T. sparrmannii, S. coulteri, S. macrocephalus and *P. philander*. This group constitutes potential invaders into the Cuvelai River itself. They are either altricial, nonguarding species *(Barbus, Clarias)* or precocial guarding or egg bearing cichlids and are all well adapted to colonise and exploit newly formed habitats in the oshanas and to survive low water conditions in pools in the upper parts of the river (Bruton 1986).

2. Later colonisers
M. acutidens, B. barnardi, B. mattozi, B. radiatus, B. unitaeniatus, M. brevianalis, L. molybdinus, S. mystus, O. macrochir, Th. buysi, P. darlingi, S. codringtoni and *S. giardi*. Fish species in this list had a limited distribution in the canal and reservoirs by 1988, 16 years after the connection was established. Some species, as M. *acutidens, B. mattozi, B. radiatus, B. unitaeniatus, L. molybdinus, Th. buysi, P. darlingi* and S. *codringtoni* had established breeding populations in the permanent reservoirs connected to the canal and can be expected to increase their distribution range, at least to permanent waters associated with the canal where no fishing is allowed. These species, however, show more specific habitat requirements than the first group and are not expected to colonise the whole Cuvelai system easily.

3. Unsuccessful invaders
H. ansorgii, M. lacerda, P. catostoma, R. maunensis, H. odoe, H. machadoi, B. bifrenatus, B. tangandensis, C. wittei, L. cylindricus, S. leopardinus, S. macrostigma, S. woosnami, Synodontis spp. *A. johnstonii, O. machadoi, Th. alboiabris, S. greenwoodi, S. angusticeps* and *S. thumbergi*. Most of this group includes species that are specialised in regards of habitat or food. These species were collected only once or twice with no indication of successful breeding having taken place yet.

4. Non-invaders
The following fish species collected in the Cunene at or near the pump intakes at Calueque and Ruacana have not been collected in Owambo : *P. castelnaui, N. multifasciatus, B. fasciolatus, B. lineomaculatus, B. thamalakanensis, L. ruddi, C. stappersii, C. theodorae*, and *A. macrurus*. Additionally the following Cunene fish species were not collected in the canal: *Kneria spp., B. afrovernayi, B. codringtonii, B. dorsolineatus, B. eutaenia, B. kerstenii, B. puellus, Zaireichthys* sp., *C. liocephalus, C. neumanni, A. katangae* and *S. robustus*. Many of these species are regarded as habitat specialists. The following are associated with swampy, thickly vegetated environments and floodplains: *P. castelnaui, N. multifasciatus, B. fasciolatus, B. puellus, A. katangae* and *C. theodorae* (Skelton *et al.* 1985), or flowing water: *Kneria* spp., *B. codringtonii, B. eutaenia, Zaireichthys* sp., *C. liocephalus, C. neumanni* and *S. robustus*. As these environments are not available in the canal, reservoirs or oshanas, the possibility of these fishes becoming established in Owambo, are slight. It is however also possible that these fish were not present in the direct environment of the intakes of the pumps at Calueque or Ruacana.

Presence of *Oreochromis mossambicus* in waters of Owambo

O. mossambicus was collected in fish production ponds at Mahanene in 1984 and in reservoirs of the Department of Water Affairs in Ondangwa in 1988. Identifications were verified by Dr P.H. Skelton, J.L.B. Smith Institute of Ichthyology. Gill raker counts of fish from Mahanene (the character used to distinguish the two *Oreochromis* species in the field) were constantly lower (18-20 on the lower half of the first arch) than for *O. andersonii*. The fish in production ponds at Mahanene originated from the reservoir at Ondangwa, then the only source of fish stocks (H. Ferreira 1975, pers. comm.). The origin of these fish remains a puzzle as they do not seem to have been introduced from the fisheries hatchery at Hardap (B. van Zyl pers. comm.). The presence of this fish species in the distribution area of the closely related and allopatric *O. andersonii* is regarded as extremely undesirable as hybridisation of these two species is likely (De Moor & Bruton 1988). This could jeopardize the genetic purity of *O. andersonii* stocks in Owambo, and in the Cunene and even the Okavango systems. Consequently, the population at Mahanene was destroyed by the Department of Agriculture in 1987 and replaced by local stocks. The population in the reservoirs at Ondangwa is presently relatively isolated from the oshanas, but should also be eliminated.

CONCLUSIONS AND RECOMMENDATIONS

Owambo has an unique oshana system that receives floodwater from an extensive separate catchment in Angola. The relatively depauperate fish community of the oshanas compared with that of the Cunene, supports this finding, especially as a number of Cunene species were quite successful in colonizing waters in Owambo after a manmade connection had been established. After more than 16 years of connection with the Cunene system, three cichlid species from the Cunene have been recorded in permanent water bodies away from the canal, including Hinakulu Yomadhiya pans. It also appears possible that some barbs *(B. poechii/trimaculatus, B. bifrenatus* and *B. radiatus)* may already have colonised the headwaters before 1976, forming a component of the efundja flood community. The scant information on the original fish life of the Cuvelai system unfortunately prevents any final conclusions. With more than 15 resident Cunene species in the canal and associated reservoirs, further colonisation of the upper Cuvelai can be expected after a number of good efundja flood years. This study emphasizes the ecological implications of intercatchment transfer of water before conducting impact studies. The absence of any preventive measures enabled not less than 46 Cunene fish species to enter the Cuvelai drainage via the canal. They survived passage through turbine pumps and a 50 mm inlet grid (F. Binneman

pers. comm.).

The following recommendations are suggested:-

1. That the further spread of Cunene species is monitored in the canal, reservoirs and particularly the oshanas during efundja floods. The extent of successful invasion of Cunene species in the Cuvelai system north of Owambo provides information on the adaptability of fish species and may indicate candidate invaders into the Eastern National Water Carrier which will connect the Kavango system with central districts of Namibia.

2. That, in the event of improved relations between Namibia and Angola, a joint research programme is initiated to study the dynamics of efundja floods and the distribution and migration of fish in the whole Cuvelai system including the northern portion in Angola.

3. That studies are undertaken on the utilisation of the temporary oshana fish populations. Adapted fish farming as proposed by Van der Waal (1988) should also be further investigated.

4. That no fish are introduced or released in the oshanas or reservoirs that are not endemic to the Cuvelai system.

5. That the *O. mossambicus* populations in the reservoirs of the Department of Water Affairs are destroyed under supervision of fish biologists.

6. That an electrophoretic study is undertaken of tilapia populations in order to establish the genetic status of fish stocks in Owambo, particularly those of the Mahanene fish breeding unit.

7. That no pipelines connecting adjacent river catchments are planned without appropriate impact assessments. No mention of influence on fishlife was made in an assessment on the present Owambo canal but considerable attention was given to preventive measures against invading gastropods (Anon 1967).

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