The diversity, distribution and abundance of the fishes in the Moremi Wildlife Reserve, Okavango Delta, Botswana

G.S. Merron

J.L.B. Smith Institute of Ichthyology, Private Bag 1015, Grahamstown, 6140 Republic of South Africa

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Between November 1983 and December 1986 fishes were collected quarterly from the Moremi Wildlife Reserve, Okavango Delta, Botswana. Four sampling sites were surveyed in the reserve, each representing a different habitat type characteristic of the area. A total of 55 121 specimens representing 62 species was collected. Species composition varied between the sampling sites with the highest diversity and abundance being recorded from perennial flowing habitats. The importance of the reserve as a refuge for fish stocks in the Delta and potential threats to the integrity of the fish community are outlined.

Tussen November 1983 en Desember 1986 is visse kwartaalliks versamel vanuit die Moremi Wildreservaat, Okavango Delta, Botswana. Vier versamelingspunte, waarvan elk 'n verskillende habitattipe verteenwoordig, is gekies. 'n Totaal van 55 121 monsters wat 62 spesies verteenwoordig, is versamel. Spesiesamestelling verskil tussen die versamelpunte, met die hoogste verskeidenheid en hoeveelheid in standhoudende vloeiende habitats. Die belangrikheid van die reservaat as 'n skuiling vir visbronne in die Delta en potensiële bedreigings vir die integriteit van die vispopulasie is ook uitgewys.

Keywords: Conservation, fisheries management, perennial and seasonal flowing habitats, species composition

Introduction

The Moremi Wildlife Reserve (MWR) in the Okavango Delta, Botswana, (Figure 1) harbours a well-studied and diverse population of birds and mammals (Tinley 1966; Ross 1987). Little information is available, however, on the fishes of the reserve. Jubb & Gaigher (1971) and Skelton, Bruton, Merron & Van der Waal (1985) reviewed the early history of ichthyological work in the Delta, including collections made in the MWR. The latter authors have a checklist of the fishes of the Okavango drainage system in Angola, Namibia and Botswana. A total of 83 species has been recorded from the entire watershed.

The fishes of the MWR are exposed to a variety of man-induced and natural perturbations and exploitation pressures. Recreational fishing is increasing as more tourists visit the reserve and an increasing number of safari camps offer fishing as an attraction. The tigerfish, *Hydrocynus vittatus*, and various species of cichlids are selectively targeted.

Parts of the MWR have been sprayed with insecticides (principally endosulfan) at least eight times since 1977 in an attempt to control the tsetse fly (*Glossina morsitans*), a vector of sleeping sickness in man and nagana in cattle (Davies & Bowles 1976). Although every effort has been made to use ultra-low volumes of insecticides which have a minimal effect on non-target organisms, fish kills have been reported after spraying operations (Douthwaite, Fox, Matthiessen & Russell-Smith 1981; Merron 1986; Merron 1992).

A water abstraction scheme at Rundu in Namibia, designed to draw off up to 4% of the inflow into the Okavango Delta, is due to start operating at the turn of the century. This water abstraction project may affect the magnitude of the flood cycle which appears to be the key factor influencing the community structure of fishes in the Okavango Delta (Merron 1991). The possible transfer of water from the northern areas of the Okavango Delta in Botswana to satisfy increasing industrial and agricultural developments further south has also been discussed (Ross 1987). In addition, periodic droughts decrease the area of the floodplains which serve as an important habitat for young fishes as well

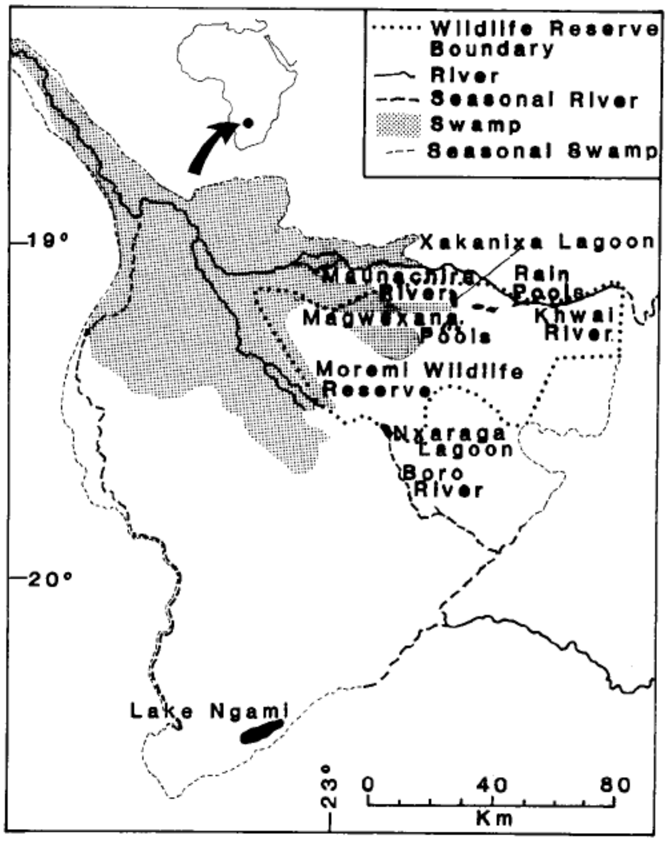

Figure 1 Map of the Okavango Delta, Botswana, showing the location of the Moremi Wildlife Reserve and sampling sites surveyed between November 1983 and December 1986.

as providing a rich source of food for adults (Bruton & Jackson 1983).

It is therefore essential that information on the fish stocks in the MWR should be made available to assist with the management of this important resource. In this paper the diversity, distribution and abundance of the fishes in relation to various habitat types and flood cycles between November 1983 and December 1986 is described.

Study area

The Moremi Wildlife Reserve is situated in the north-eastern part of the Okavango Delta (Figure 1). The geology, climate, vegetation and distribution of large mammals in the reserve have been described by Tinley (1966), while the physical, chemical and biological characteristics of the Okavango Delta have been reviewed by Thompson (1976), Wilson & Dincer (1976), Campbell (1980) and Ross (1987).

The Okavango Delta is a wetland ecosystem that receives an annual flood from the highlands of southern Angola. The flood waters usually enter the northern Okavango Delta in January, reaching Xakanixa Lagoon in the MWR (Figure 1) in June. The timing, magnitude, duration and cycle of high and low water levels of the annual flood vary inter-annually. The flow of water through the MWR can be influenced by sediment transport and channel blockages (McCarthy, Ellery, Rogers, Cairncross & Ellery 1986). In terms of its hydrology, the waterways of the reserve are more stable (predictable) in the perennially flowing north-western regions and less stable (unpredictable) in the seasonally flowing east and south-east regions.

Four major habitat types were surveyed in the MWR; a perennial flowing mainstream channel and lagoon (e.g. Maunachira River and Xakanixa Lagoon), a seasonal flowing mainstream channel and lagoon (e.g. Boro River and Nxaraga Lagoon), perennial floodplain-connected lagoons (e.g. Magwexana Pools), and ephemeral rain pools along the Khwai floodplain (Figure 1).

Wetlands, such as the Okavango Delta, typically have high biological productivity. The Okavango system is, however, low in available nutrients when compared with other tropical wetlands (Thompson 1976). Much of the nutrient input into the aquatic ecosystem of the MWR comes from decomposing aquatic macrophytes and dung deposited by the large numbers of mammals and birds that frequent the water-bodies and floodplains. The limnology of the reserve has, however, not yet been fully studied.

Material and Methods

From November 1983 until December 1986 a gillnet fleet consisting of 25-m panels of stretch-mesh sizes 24, 40, 50, 60, 75, 96, 110 and 143 mm was set on a quarterly basis at all sites. On average four collections were made during each survey period resulting in a total of 50 net-nights for the Maunachira River and Xakanixa Lagoon, 51 for the Boro River and Nxaraga Lagoon, 50 for Magwexana Pools and 45 for the rain pools. At times, crocodiles and hippopotamuses damaged the nets.

A 12-mm stretched-mesh seine net and the ichthyocide rotenone were also used in all sampling sites throughout the study period. A total of 61 collections were made within the Maunachira and Xakanixa sites, 62 within the Boro and Nxaraga sites, 60 at Magwexana Pools and 46 within the rain pools.

Fish captured in gillnets were measured for standard length (SL) to the nearest millimetre and weighed in the field to the nearest gram on a digital balance. All fishes caught in seine nets or with rotenone were fixed in 10% formalin and brought back to the J.L.B. Smith Institute of Ichthyology for analysis. These fishes were identified, sorted, weighed and stored in 50% iso-propanol.

The data were used to construct pie diagrams of species composition and relative abundance, based on numbers and mass, for the entire MWR fish fauna. All collections within a given sampling site between November 1983 and December 1986 were grouped together for this analysis. As the pie diagrams only allow 12 slices, one group of fishes represented in the pie charts labelled 'Others' requires further mention. The group 'Others' represents species which contributed, on average, less than 1% each to the total number or mass of fish. It should be noted that within the genus *Synodontis* only four species (i.e. *S. leopardinus*, *S. nigromaculatus*, *S. macrostigma* and *S. woosnami*) were recognized in the present analysis, although Skelton & White (1990) now recognize two additional species (i.e. *S. macrostoma* and *S. vanderwaali*).

The distribution and abundance of each species, and therefore, of the communities in different habitat types, was tabulated. The 17 species of the family Cichlidae contributed considerably to the numeric and mass compositions of the communities relative to other families of fish. Therefore, to obtain a general trend in community structure of the different habitat types, reference is made to the groups of cichlid and non-cichlid species when the species compositions of the different sites is being referred to.

The standardized gillnet, seine net and rotenone sampling carried out during each quarterly survey were analysed on a seasonal basis to determine the catch per unit effort (CPUE) for each site in response to the annual flood. This analysis entailed grouping each collection of fish made within each sampling site according to four distinct flood levels (i.e. receding, low, filling and high water levels). It should be emphasized that the quarterly surveys were conducted in such a way that the different techniques and efforts in different habitats were comparable.

Results

A total of 55 121 specimens comprising 62 species with a combined mass of 1576 kg was collected in the MWR between November 1983 and December 1986 (Table 1).

Numerically, the most common cichlid species (Figure 2a) were *Oreochromis andersonii* (9,1%), *Tilapia sparrmanii* (4,7%), *T. rendalli* (3,7%) and *Pseudocrenilabrus philander* (4,5%). Common non-cichlid species were *Aplocheilichthys johnstoni* (7,9%), *Brycinus lateralis* (5,7%), *Schilbe intermedius* (4,4%), *Barbus haasianus* (4,9%), *B. thamalakanensis* (4,9%), *B. paludinosus* (4,4%) and *B. barnardi* (3,1%). The group 'Others' (42,7%) represents a total of 51 additional species.

Table 1 Species composition and percentage number and mass of fish collected from four sampling sites in the Moremi Wildlife Reserve, Okavango Delta, Botswana, between November 1983 and December 1986

	Sampling site*							
	1		2		3		4	
Species	No.	Mass	No.	Mass	No.	Mass	No.	Mass
Mormyridae								
Hippopotamyrus discorhynchus	0.10	0.01	0.13	0.03				
Marcusenius macrolepidotus	4.67	2.90	2.15	1.96	3.78	2.39	0.03	0.07
Mormyrus lacerda	0.08	0.62	0.15	1.50	0.19	0.64		
Petrocephalus catostoma	3.67	0.47	1.58	0.40	2.35	0.37		
Pollimyrus castelnaui	2.60	0.17	0.43	0.07	1.94	0.22		
Characidae								
Brycinus lateralis	7.34	0.97	7.79	0.74	5.87	0.34	0.62	0.17
Hydrocynus vittatus	6.45	29.20	0.01	0.06	3.71	10.30		
Micralestes acutidens	6.42	0.26	0.15	0.02	2.82	0.14		
Rhabdalestes maunensis	1.88	0.02	1.29	0.03	1.74	0.03	0.28	0.01
Hepsetidae								
Hepsetus odoë	0.29	1.20	2.32	17.40	0.63	3.90	0.13	1.60
Distichodontidae								
Hemigrammocharax machadoi	6.47	0.05	0.70	0.01	3.32	0.03		
H. multifasciatus	1.56	0.04	0.31	0.02	0.98	0.03		
Cyprinidae								
Barbus afrovernayi	0.92	0.01	3.73	0.12	0.79	0.02		
B. barnardi	2.02	0.02	5.68	0.16	1.54	0.04	1.38	0.07
B. bifrenatus	1.05	0.04	2.59	0.18	0.62	0.02	2.71	0.35
B. eutaenia	0.11	<0.01			0.04	<0.01		
B. fasciolatus	1.86	0.03	0.53	0.02	2.79	0.07		
B. haasianus	3.09	0.01	5.77	0.07	10.78	0.12		
B. multilineatus	0.40	<0.01	1.11	0.03	0.19	<0.01		
B. paludinosus	0.11	<0.01	0.51	0.02	2.05	0.04	16.88	4.10
B. poechii	1.44	0.11	1.20	0.20	0.86	0.09	1.11	0.40
B. radiatus	2.54	0.06	1.29	0.04	2.87	0.10	0.76	0.21
B. thamalakenensis	2.28	0.03	6.73	0.20	2.92	0.05	6.25	0.44
B. unitaeniatus	0.02	0.01	0.08	0.01	0.32	0.04		
Coptostomabarbus wittei	0.86	0.01	4.05	0.04	4.38	0.02		
Labeo cylindricus	0.06	<0.01						
L. lunatus	0.10	0.27	0.02	0.23	0.31	10.70		
Opsaridium zambezensis	0.02	<0.01	0.02	<0.01	0.02	<0.01		
Bagridae								
Auchenoglanis ngamensis	0.11	0.06	0.21	0.19	0.01	0.01		
Zaireichthys spp.	0.02	<0.01	0.24	0.01	0.04	<0.01		
Schilbeidae								
Schilbe intermedius	4.92	6.80	6.64	14.70	4.24	7.00	0.36	1.20
Clariidae								
Clarias gariepinus	2.42	15.10	0.44	7.00	1.29	11.80	2.83	8.90
C. ngamensis	0.92	5.70	0.28	3.40	0.35	4.70	0.28	3.50
C. stappersi	0.06	0.03	0.01	0.01	0.01	0.04		
C. theodorae	0.17	0.02	0.12	0.04	0.12	0.02		
Mochokidae								
Synodontis leopardinus	1.27	0.52	1.31	4.20	0.46	0.48		
S. macrostigma	1.82	1.52	0.55	0.88	0.61	0.58		
S. nigromaculatus	2.69	3.70	1.48	5.80	2.21	3.50		
S. woosnami	0.95	0.86	0.59	0.95	0.64	0.38		
Poeciliidae								
Aplocheilichthys hutereaui	0.34	<0.01	2.36	0.02	1.29	0.01	0.36	0.01
A. johnstoni	7.25	0.04	12.01	0.17	7.17	0.03	2.49	0.14
A. katangae	0.11	<0.01	0.20	<0.01	0.23	<0.01		
Cichlidae								
Hemichromis elongatus	0.16	0.09	0.07	0.08	0.24	0.09		
Oreochromis andersonii	3.42	7.40	4.72	9.80	3.01	13.80	26.90	37.50

Table 1 Continued

Species	Sampling site* 1 No.	1 Mass	2 No.	2 Mass	3 No.	3 Mass	4 No.	4 Mass
O. macrochir	0.74	1.60	1.39	2.80	0.99	4.90	6.38	14.70
Pharyngochromis darlingi	1.73	0.11	1.91	0.18	1.37	0.07	2.30	0.28
Pseudocrenilabrus philander	3.53	0.19	1.87	0.11	6.25	0.18	8.24	1.40
Serranochromis (Sargochromis) carlottae	0.44	1.25	0.17	0.73	0.36	0.89		
S. (Sar.) codringtoni	0.26	0.46	1.40	1.80	0.61	1.24	0.29	1.10
S. (Sar.) giardi	0.23	1.17	0.53	2.53	0.35	1.73		
S. (Sar.) greenwoodi	0.03	0.06	0.07	0.30	0.09	0.19		
S. (Serranochromis) angusticepts	1.97	8.90	0.95	7.90	2.42	11.30	0.15	0.64
S. (S.) longimanus	0.03	0.02	0.12	0.25	0.02	0.12		
S. (S.) macrocephalus	0.16	0.50	0.30	0.60	0.23	0.79		
S. (S.) robustus jallae	1.21	3.80	0.15	3.50	0.37	1.39		
S. (S.) thumbergi	0.05	0.15	0.26	0.99	0.07	0.32	0.11	0.76
Tilapia rendalli rendalli	0.71	1.29	1.73	2.66	2.66	3.00	10.77	17.30
T. sparrmanii	3.26	2.00	6.36	4.70	3.24	0.03	4.71	4.30
T. ruweti	0.08	0.01	1.04	0.11	1.05	0.19	2.71	1.07
Anabantidae								
Ctenopoma intermedium	0.09	<0.01	0.07	0.01	0.05	<0.01		
C. multispinus	0.02	<0.01	0.05	0.02	0.01	<0.01	0.38	0.41
Athieomastacembelidae								
Athieomastacembelus frenatus	0.27	0.03	0.08	0.01	0.12	0.02		
Total no. species	62		59		60		28	
Total no. specimens	11327		20188		11261		12345	
Total mass (kg)	599		481		394		102	

* 1 = Xakanixa Lagoon and Maunachira River; 2 = Nxaraga Lagoon and Boro River; 3 = Magwexana Pools; 4 = Rain pools

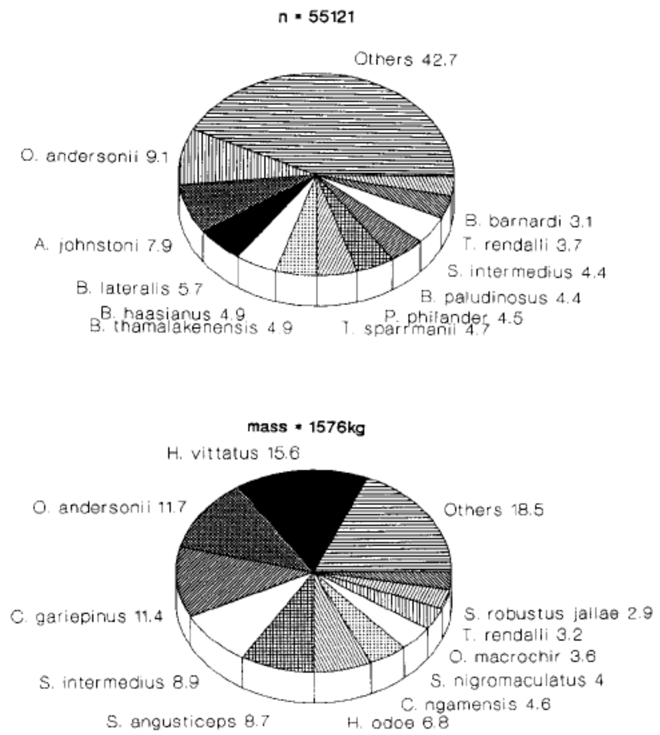

Figure 2 Total number (a) and mass (b) of fish collected, using all the sampling methods, from the Moremi Wildlife Reserve, Okavango Delta, between November 1983 and December 1986.

The results on mass composition of all MWR fishes (Figure 2b) indicate that important cichlid species included *Oreochromis andersonii* (11,7%), *O. macrochir* (3,6%), *Serranochromis angusticeps* (8,7%), *S. robustus jallae* (2,9%) and *Tilapia rendalli* (3,2%). Important non-cichlid species included *Hydrocynus vittatus* (15,6%), *Clarias gariepinus* (11,4%), *C. ngamensis* (4,6%), *S. intermedius* (8,9%), *Hepsetus odoë* (6,8%) and *Synodontis nigromaculatus* (4,0%). The remaining 51 species in the group 'Others' contributed 18,5% to the total mass value.

These results on species diversity and relative abundance for the entire MWR were then used as a foundation on which to compare interspecific variations in faunal associations between the four main habitat types.

Distribution and abundance of fish species for each habitat type

Maunachira River and Xakanixa Lagoon

A total of 11 327 specimens, representing 62 species with a combined mass of 599 kg, was collected from this site (Table 1). Numerically, the most common fishes were non-cichlids including *B. lateralis* (7,3%), *A. johnstoni* (7,2%), *Hemigrammocharax machadoi* (6,5%), *H. vittatus* (6,5%), *Micralestes acutidens* (6,4%), *S. intermedius* (4,9%), *Marcusenius macrolepidotus* (4,7%) and *Petrocephalus* *catostoma* (4,7%). The only common cichlids in the numerical analysis were *Pseudocrenilabrus philander* (3,5%), *O. andersonii* (3,4%) and *T. sparrmanii* (3,3%). The remaining 51 species contributed 41,6% to the total.

In terms of mass contributions (Table 1), the most important non-cichlid species were *H. vittatus* (29,2%), *Clarias gariepinus* (15,1%), *C. ngamensis* (5,7%) and *S. intermedius* (6,8%). The only two important cichlid species were *S. angusticeps* (8,9%) and *O. andersonii* (7,4%). The remaining species contributed 12,8% of the total.

One of the most striking features of this habitat type when compared with the overall MWR fish fauna is the relative increase in abundance of *Hydrocynus vittatus* and decrease of *Hepsetus odoë*.

Boro River and Nxaraga Lagoon

A total of 20 188 specimens, representing 59 species with a combined mass of 481 kg, was collected from this site (Table 1). Numerically, the community was dominated by non-cichlid species of which *A. johnstoni* (12.1%), *Brycinus lateralis* (7,8%), *S. intermedius* (6,6%), *Barbus barnardi* (5,7%), *B. thamalakanensis* (6,7%), *B. haasianus* (5,8%), *B. afrovernayi* (3,7%), *B. bifrenatus* (2,6%) and *Coptostomabarbus wittei* (4,0%) were the most common. Only two cichlid species, *T. sparrmanii* (6,4%) and *O. andersonii* (4,7%), were common. The remaining 49 species contributed 33,9% to the total.

In terms of mass contribution (Table 1), important non-cichlid species included *H. odoë* (17,4%), *S. intermedius* (14,7%), *Clarias gariepinus* (7,0%), *C. ngamensis* (3,4%), *Synodontis leopardinus* (4,2%) and *S. nigromaculatus* (5,8%). Important cichlid species included *Oreochromis andersonii* (9,8%), *O. macrochir* (2,8%), *Serranochromis angusticeps* (7,9%), *S. robustus jallae* (3,5%) and *T. sparrmanii* (4,7%). The remaining species contributed 18,8% to the total.

The relative decrease in *H. vittatus* and increase in *H. odoë* relative to their proportional contributions to the entire MWR fauna characterize this habitat type and is in sharp contrast to the data presented for the former habitat type.

Magwexana Pools

A total of 11 261 specimens, representing 60 species with a combined mass of 394 kg, was collected from this site (Table 1). Numerically, the most important species were non-cichlids which included *Barbus haasianus* (10,8%), *A. johnstoni* (7,2%), *Brycinus lateralis* (5,9%), *C. wittei* (4,4%), *S. intermedius* (4,2%), *M. macrolepidotus* (3,8%), *Hydrocynus vittatus* (3,7%) and *Hemigrammocharax machadoi* (3,3%). The only prominent cichlid species in the numerical composition were *P. philander* (6,3%), *T. sparrmanii* (3,2%) and *O. andersonii* (3,0%). The remaining 51 species contributed 44,2% to the total.

The most substantial mass contributions were recorded for the non-cichlid species of which *Clarias gariepinus* (11,8%), *C. ngamensis* (4,7%), *Labeo lunatus* (10,7%), *H. vittatus* (10,3%), *Schilbe intermedius* (7,0%) and *Synodontis nigromaculatus* (3,5%) were the most common (Table 1). Important cichlid species included *Oreochromis andersonii* (13,8%), *O. macrochir* (4,9%), *Serranochromis angusticeps* (11,3%) and *T. rendalli* (3,0%). The remaining species contributed 15,0% to the total.

The appearance of large numbers of *L. lunatus* and the relative decrease in abundance and mass of *H. odoë* are important features of the fish fauna in this habitat type.

Rain pools

A total of 12 345 specimens, representing 28 species with a combined mass of 102 kg, was collected from these sites (Table 1). Species diversity and the total catch, based on similar effort, were the lowest recorded for any habitat type.

Numerically, the most common cichlid species (Table 1) were *Oreochromis andersonii* (26,9%), *O. macrochir* (6,4%), *Tilapia rendalli* (10,8%), *T. sparrmanii* (4,7%), *T. ruweti* (2,7%) and *P. philander* (8,2%). The non-cichlids were dominated by *Barbus paludinosus* (16,9%), *B. thamalakanensis* (6,3%), *B. bifrenatus* (2,7%), *C. gariepinus* (2,8%) and *A. johnstoni* (2,5%). The remaining 17 species contributed 9,1% to the total.

In terms of mass contributions (Table 1), the most important cichlids were *Oreochromis andersonii* (37,5%), *O. macrochir* (14,7%), *Tilapia rendalli* (17,3%), *T. sparrmanii* (4,3%), *P. philander* (1,4%) and *S. codringtoni* (1,1%). Important non-cichlids included *Clarias gariepinus* (8,9%), *C. ngamensis* (3,5%), *B. paludinosus* (4,1%), *S. intermedius* (1,2%) and *H. odoë* (1,6%). The remaining species contributed 5,0% to the total.

The high percentage occurrence of *O. andersonii* and *T. rendalli* and low abundance of *H. odoë* when compared with the overall MWR fauna characterize this habitat type. *H. vittatus* was absent from rain pools.

Community similarities

The relative abundance of several species, based on mass, varied between sampling sites (e.g. *Hydrocynus vittatus* and *Hepsetus odoë*). However, the only significant difference ($P < 0.001$) in community structure of fish between the four sampling sites using a two-way ANOVA was in the rain pools. No significant difference was found between the communities of fish collected in the other sampling sites ($F = 16,836$; df 3,183).

Demography of the fish population in different habitat types to the annual flood cycle

Maunachira River and Xakanixa Lagoon

The Maunachira River and Xakanixa Lagoon were first surveyed during the receding water levels in November 1983. The CPUE, based on all sampling methods, was 43,77 kg (Figure 3a). During the low water level in March 1984 a higher CPUE of 53,75 kg was recorded, compared with November 1983. During the filling phase in June 1984 the CPUE was 54,48 kg. The CPUE for August 1984, during the high water level, was the highest recorded for the 1983/84 flood season (61,9 kg).

In November 1984, during the receding flood level, a decrease in the CPUE was recorded (35,92 kg, Figure 3a). Similar results for the CPUE were obtained during the 1985 and 1986 sampling periods. An increase in the CPUE was recorded between 1983 and 1986 (Figure 3a).

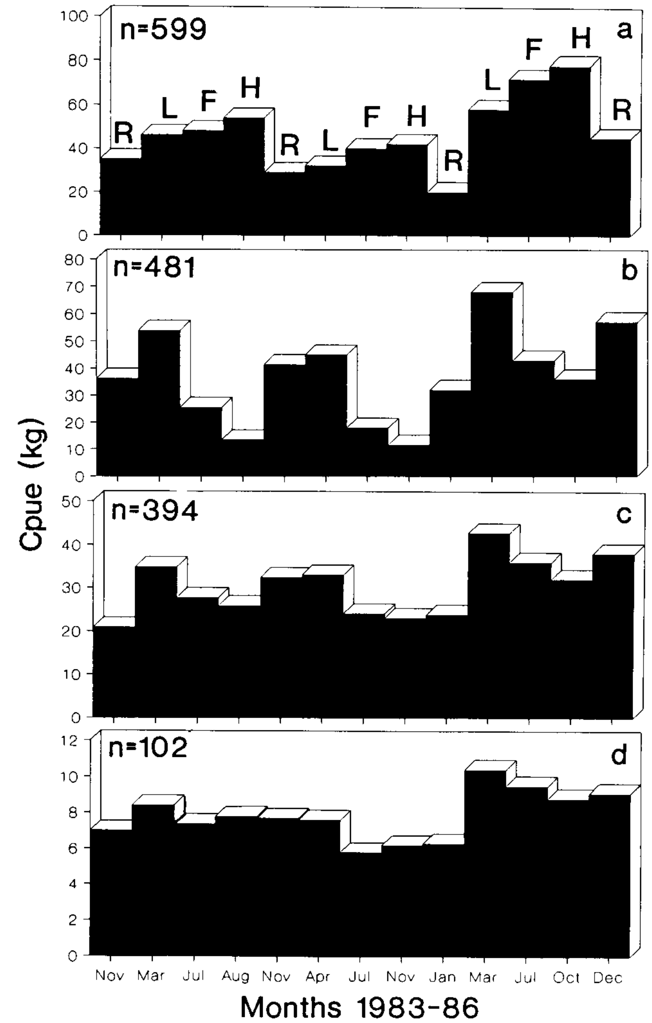

Figure 3 The catch per unit effort based on all the sampling methods for the four sampling sites in the Moremi Wildlife Reserve, Okavango Delta, between the period November 1983 and December 1986. The various flood levels are:- R = receding; L = low; F = filling; H = high flood levels.

Boro River and Nxaraga Lagoon

In November 1983 the water level at Nxaraga Lagoon was receding and the surrounding floodplains were dry. The Boro River entering the Nxaraga Lagoon was, on average, about 7 m wide and 0,5 m deep. A CPUE of 36,21 kg was recorded (Figure 3b).

In March 1984 the extensive littoral zones, evident in November 1983, were greatly reduced in size. The Boro River leading into the Nxaraga Lagoon was about 2 m wide and less than 0,3 m deep and all the surrounding floodplains were dry. Fish populations were concentrated and a high CPUE of 53,78 kg was recorded (Figure 3b).

Nxaraga Lagoon was next sampled in July 1984, after the relatively high flood which reached this area in April/May 1984. The lagoon had greatly increased in size with an extensive littoral zone and large areas of surrounding inundated floodplain. The CPUE had dropped markedly to 25,51 kg, lower than either the November 1983 or March 1984 values (Figure 3b). This trend probably reflects the movement of fish into previously dry areas.

During the period of high water level in August 1984, the CPUE dropped slightly, relative to that recorded in June 1984, to a value of 13,5 kg (Figure 3b). By November 1984 the water level at Nxaraga Lagoon was again receding. The CPUE of the fish (41,38 kg) was higher than that during the same time period in 1983 (Figure 3b).

A similar pattern of change in CPUE was evident during the 1985 and 1986 sampling periods (Figure 3b). The highest CPUE was recorded during the receding and low water levels when stocks were concentrated. This is in contrast to the finding along the Maunachira River and Xakanixa Lagoon where an increase in CPUE was recorded during the filling and high water levels. The range of the CPUE fluctuated more than at the former site. An increase in catch between 1983 and 1986 was also recorded (Figure 3b).

Magwexana Pools

The Magwexana Pools were first surveyed during the receding water level in November 1983. The CPUE, based on all sampling methods, was 20,82 kg (Figure 3c). During the low water level in March 1984 an increase to 34,81 kg was recorded.

During the arrival of the flood waters in July 1984 (i.e. filling phase), the CPUE decreased to 27,66 kg (Figure 3c). During the high water level in August 1984, the CPUE was 25,82 kg. In November 1984, the water level again receded and the CPUE increased to 32,39 kg.

Similar changes in CPUE were apparent during the 1985 and 1986 sampling periods (Figure 3c). The amplitude of change in the CPUE was relatively consistent when compared with the former sites. An increase in CPUE during the sampling period was also evident and is similar to the findings recorded for the previous sites.

Rain pools

The rain pool habitat type was first surveyed during the receding water phase in November 1983. The CPUE, based on all the sampling methods, was 7,04 kg (Figure 3d). This was the lowest CPUE recorded for any previous sampling site. During the low water level in March 1984 the CPUE was slightly higher (8,43 kg; Figure 3d). In July 1984 the rain pools were connected to the main floodplain and a slight decrease in CPUE was apparent (7,44 kg; Figure 3d), possibly due to dispersal. In August 1984, during the high water level, the CPUE was 7,82 kg (Figure 3d) whereas in November 1984, during the receding water level, a CPUE of 7,65 kg was recorded (Figure 3d). Similar results were obtained during the 1985 and 1986 sampling periods (Figure 3d). The range in the CPUE was minimal, although this may be an artifact of the relative ease of collecting fish within rain pools.

Discussion

The fish of the Moremi Wildlife Reserve are an important natural resource for Botswana. Within the southern African geographic region, the MWR has a high diversity of fishes with 62 species having been recorded during this survey period. Only two rare species, *Nannocharax macropterus* and *Chiloglanis fasciatus*, that have previously been recorded from the Okavango riverine floodplain (Merron

1991) were not collected in the MWR.

The relative abundance of the different species varies between sites, although the only significantly different fish community was found at the rain pool sampling site. The virtual absence of *H. vittatus* from the Boro River and Nxaraga Lagoon can be related to their preference for large, relatively clear and flowing water bodies (e.g. Maunachira River and Xakanixa Lagoon). *H. odoë*, on the other hand, was more common in Nxaraga Lagoon than in Xakanixa Lagoon as *H. odoë* prefers well-vegetated areas. Being an ambush predator, *H. odoë* relies on dense vegetation for cover while waiting for prey (Merron 1991). These observations on habitat preferences are in agreement with the findings in other similar African wetland systems such as the Kwando-Linyanti-Chobe River systems (Van der Waal 1985; Merron 1989) and Zambezi River system (Jackson 1961).

The proportion of cichlids in the community at both Nxaraga Lagoon and Magwexana Pools was considerably more than the proportion found in Xakanixa Lagoon where non-cichlids contributed a higher percentage to the ichthyomass. The rain pool habitat type harboured a depauperate fauna and was dominated by a few relatively small species (<200 mm SL).

The major factor determining the distribution and abundance of fishes in the MWR appears to be habitat preferences, with the physical characteristics of the environment playing a major role. The permanence of the water (i.e. retention time) and the nature of its flow are two of the most obvious ecological factors influencing community structure. These two factors influence other physico-chemical parameters in the reserve, such as substrate type, extent of emergent, submergent and floating macrophyte cover, dissolved oxygen values, water temperatures, etc. which affect the distribution of fishes.

Based on standardized CPUE figures for the mass contribution to individual sites, the catch was highest in the perennially flowing Maunachira River and Xakanixa Lagoon and, with the exception of ephemeral rain pools, lowest in the seasonally flowing Boro River and Nxaraga Lagoon. The degree of change in the amplitude of the CPUE was also relatively more uniform with time in the perennially flowing habitat types relative to that found in the seasonally flowing Boro River and Nxaraga Lagoon.

Merron (1991) showed that the catch composition varied during the flood cycle, despite the fact that diversity did not change. For example, at high water levels in Xakanixa Lagoon a greater mass contribution of *H. vittatus* and *C. gariepinus* was recorded while during the receding and low water levels the mass contribution of *O. andersonii* increased. The overall increase in the CPUE of all species during the filling and high water levels in Xakanixa Lagoon was in contrast to that recorded for Nxaraga Lagoon where an increase in CPUE was apparent during receding and low water levels.

The relatively stable CPUE in Magwexana Pools may reflect the presence of large numbers of hippopotami in this lagoon which serve to enrich the system by defaecating in the water. Magwexana Pools also harbours the largest concentration of *Labeo lunatus* thus recorded from the Delta and emphasizes the importance of the reserve in providing a refuge for rarer fish species.

The total ichthyomass of the reserve varies considerably in relation to fluctuations in water level. Welcomme (1979) showed that the yield from a river-associated wetland fishery is reasonably well correlated with the flood history of the previous two years. This is due to the flood-dependent spawning behaviour of many of the fish species. Periods of high water level result in a larger percentage of the population being able to spawn successfully, and also create vast nursery areas for the young. Although a longer time series of data are required to accurately predict the total ichthyomass in the reserve, the results presented here indicated a 20% increase in the catch in December 1986 compared with that in November 1983. This is two years after the high flood of 1984 and supports Welcomme's (1979) prediction.

Although the MWR serves as a microcosm of the ichthyofauna of the Delta, it cannot be managed in isolation from the rest of the Delta. The conservation of the fishes and habitats of the MWR depends on the dynamics of the Delta as the fish populations depend directly on the water quality and quantity flowing into the reserve. Water draw-off projects upstream of the reserve, such as the Eastern National Water Carrier in Namibia, could affect the water flow characteristics and the fish fauna of the MWR. The aquatic resources of the reserve cannot be 'fenced off', as has been done with the terrestrial component of many southern African wildlife reserves. Any management plan must take into account the ebb and flow of the fish populations of the MWR in response to the seasonal water level fluctuations.

Other artificial perturbations, such as increases in recreational fishing, could also contribute to changes in the community structure of the fishes. At present eight safari camps offer fishing as an attraction and an increasing frequency of *'ad hoc'* fishing by independent tourists takes place. Although the Department of Wildlife and National Parks (DWNP) issues a license to catch ten fish per day on hook and line, no information on the total catch is available. In other wetlands, selective fishing pressure has resulted in the decline of stocks of the larger species, which are replaced by smaller and less desirable species (Welcomme 1979).

Periodic insecticide spraying, particularly using the organochlorine endosulfan, could result in a 75% reduction in the nesting density of *Tilapia rendalli* and also affect the population density of other fish species (Douthwaite *et al.* 1981). Although the Moremi Wildlife Reserve management plan submitted in 1991 favours the use of endosulfan (E. Patterson, pers. comm.), Merron (1992) provides evidence that the use of the pyrethroid deltamethrin, used on the reserve in 1991, had a significantly lower impact on fish and other aquatic organisms than endosulfan formulations.

There have also been periodic outbreaks of the exotic water plant *Salvinia molesta* within the MWR. Although a biological control programme, using the introduced weevil *Cyrtobagous salviniae*, has been successful (Department of Water Affairs 1992), the spread of this noxious plant could still pose a problem. The growth rate of *S. molesta* is rapid and, in the absence of a natural grazer, it could rapidly cover an entire lagoon, as witnessed at Xini Lagoon (Figure 1) in 1986 (Merron 1991). The establishment of *Salvinia* mats leads to the exclusion of light, thus reducing primary productivity and nutrient exchange. This results in a reduction in oxygen concentrations to levels that are unsuitable for most fish species. The spread of *Salvinia* could also lead to a large reduction in seasonally inundated floodplains by upsetting the natural flow patterns (Smith 1985). In addition, the water hyacinth (*Eichornia crassipes*), another noxious plant which has established itself in Zimbabwe and South Africa, could also be an ecological hazard if it were to establish itself in any areas of the Okavango (Department of Water Affairs 1992).

The fishes of the MWR are important for maintaining many ecological processes and should be managed in such a way that they can sustain themselves, which in turn depends on the conservation of bio-diversity and the maintenance of essential physical processes, such as flooding and draining.

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