Chapter 3: Effects of flood releases on community structure and diversity of fish in the Phongolo Floodplain.

3.1 Introduction

Impoundment of rivers worldwide has put pressure on the river systems and often flow regulated segments of the river are the only available habitat for fauna and flora (Freeman *et al.,* 2001). The management of river flow in these segments is an important element not only in conserving, protecting and allowing riverine species to recover, but in maintaining the ecological integrity of the river (Bain *et al.,* 1988; Freeman *et al.,* 2001; Kobza *et al.,* 2004). Habitat assessments as well as fish community structure are widely used to assess the environmental quality of flow altered river systems (Bain *et al.,* 1988; Merron *et al.,* 1993a; Kobza *et al.,* 2004; Naghibi & Lence, 2012). Fish community structures are directly influenced by the available habitat, which in turn, is directly influenced by the flow regime, making it a complex and critical component for the management of ecosystems (Bain *et al.,* 1988; Naghibi & Lence, 2012).

Altering a river's natural flow is one of humankind's, if not the biggest, disturbances of the environment (Bain *et al.,* 1988). The extent of this impact is so great that most of the rivers in the northern third of the world are either moderately or strongly affected by impoundment, fragmentation, interbasin diversion or irrigation (Dynesius & Nilsson, 1994). A number of studies have been done over the last three decades to determine the effect of altering flow on fish communities and populations. (Bain *et al.,* 1988; Merron *et al.,* 1993a; Freeman *et al.,* 2001; Kobza *et al.,* 2004; Naghibi & Lence, 2012). These studies emphasize the importance of maintaining a minimum hydrological flow standards to ensure that aquatic organisms can survive droughts (Naghibi & Lence, 2012). Fish communities and populations are assumed to be in balance under natural conditions, but when there are unnatural disturbances such as flow alterations these communities are effected. Fish community structure creates a platform to identify major stressors in the system, both in the immediate and long term (Naghibi & Lence, 2012).

Naghibi & Lence (2012) graphically illustrated the effect of flooding on fish populations (Figure 3.1) and go on to explain that when a high flow event such as a flood occurs the fish experience an immediate impact via egg loss, mortality and change in habitat. Point 2 can be considered as the point where the high flow event is finished. Point 2* indicates the normal fish population if there were no flood.

The area between point 2 and 3 is the phase where fish will recover to ultimately reach equilibrium again, which can be either above or below where the original fish population was, but is more often than not below this point.
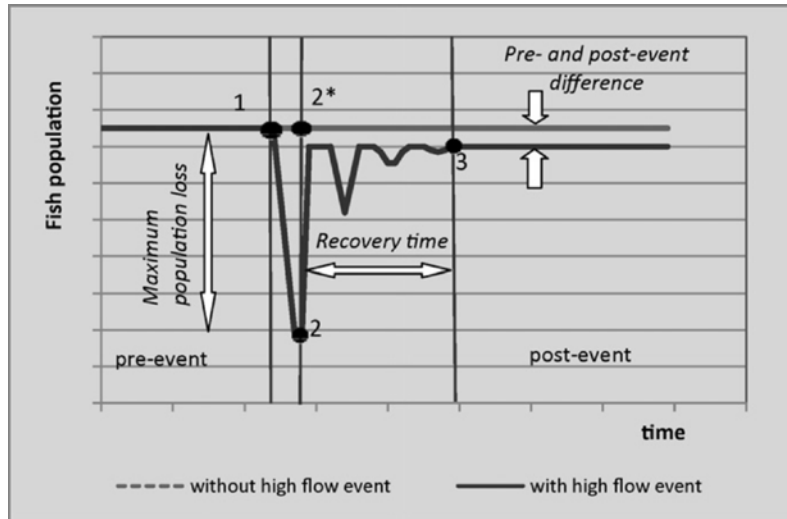
Figure 3.1: Fish population dynamics during a flooding event.

Point 1 = high flow event such as a flood. Point 2 = high flow event finished.
Point 2* = normal fish population if there were no flood. Point 3 = new equilibrium
after the flood. (From Naghibi & Lence, 2012).

Competition for water between social, economic and ecological sectors is one of the major difficulties faced when trying to manage a natural resource such as a river (Naghibi & Lence, 2012). These sectors need to be in a balance. In the Phongolo Floodplain there is a major need for water for irrigation of sugar cane on the fertile soils of the Makatini Flats east of the Pongolapoort Dam, but also from the local people living along the banks of the river who utilize the river for their livelihood (Naghibi & Lence, 2012).

Thus the aim of this chapter is to determine the current community structure of fish in the Phongolo River and floodplain in order to evaluate the effect of irregular flood releases on the community structures based on historic data (Merron *et al.*, 1993a–b; Merron *et al.,* 1994 a–e). The same sampling techniques used to collect the historic data will be used in the present study. A number of additional sites were included in the present study to determine their fish community structure as part of aims 2 and 3 of the dissertation (Chapter 1).

3.2 Historic data review

3.2.1 Flow after the dam was built

In the period 1973 to 1987, the Department of Water Affairs (DWA) managed the dam without any consultation with stakeholders, which raised growing concerns about the need for flood releases to maintain ecological services (PRESPA, 2009). Scientists proposed a flood release scheme aimed to maintain ecosystem services, but were overpowered by the surrounding farmers who were in need of irrigation water. These farmers in effect controlled the releases by negotiated releases which deviated from the original flow regime suggested by scientists (PRESPA, 2009). This had a major effect on the local communities living in the floodplain whose livelihoods depend on the floodplain as they also use the water for irrigation and catch fish from the river. The community members were resentful because of the uncertainty regarding the flood releases. As a result of these differences between farmers and floodplain communities, the need for a Water User Committee arose. In 1986 three such committees were formed for the upper, middle and lower sections of the floodplain. Although this was an improved situation than before, there were divergences between ecologists and commercial agriculture regarding the timing and size of the floods. The informal committees were replaced by a statutory Water Users' Association (WUA). This association was to be responsible for facilitation in governing the flood releases and to promote economic efficiency and environmental integrity throughout the floodplain.

According to the National Water Act (1998), statutorily the WUA was established to promote a decentralized management of water resources at community level, mainly in order to create a single channel of communication to the DWA. The idea was for the WUA to collect money from their members, formulate a business plan, to privately raise other resources and expand the remit of its function from consultative decision-making for flood releases to the integrated development of the floodplain. Since the WUA was established some 10 years ago, none of this has happened (PRESPA, 2009).
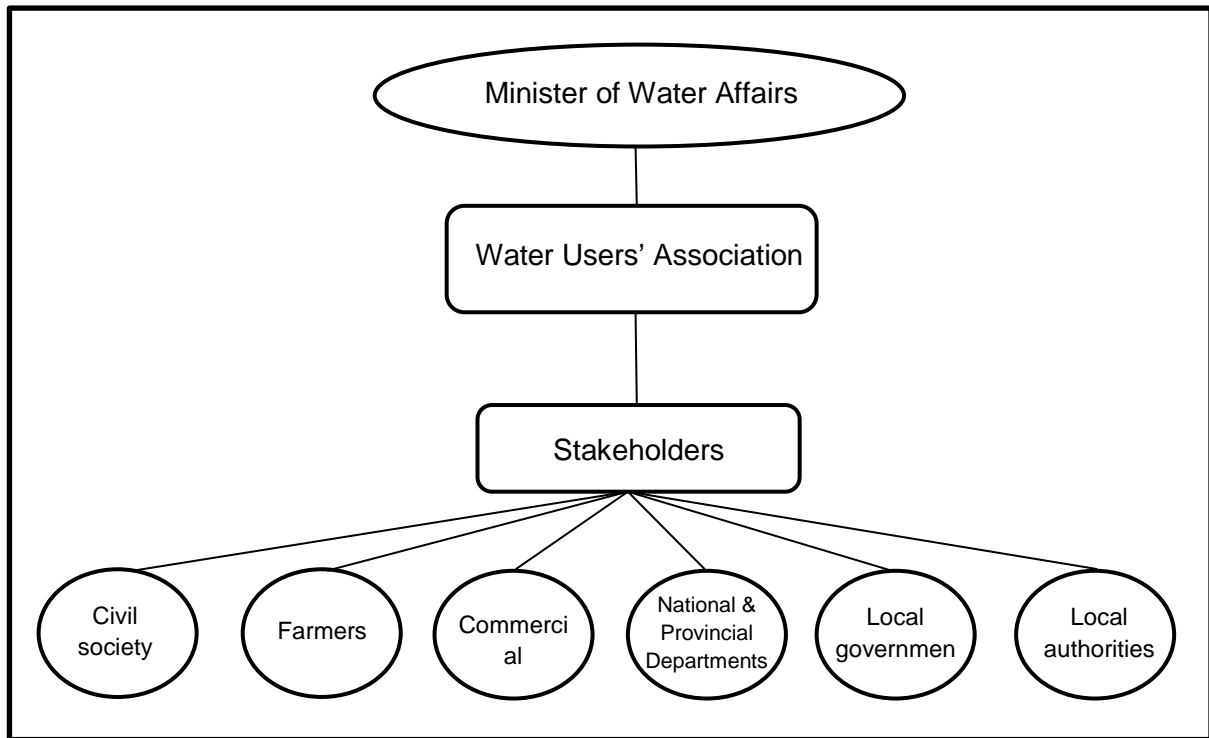
Figure 3.2: The institutional structure of the Water Users' Association.

Merron *et al.* (1993a) studied the changes in fish communities of the Phongolo Floodplain before (1974-6), during (1983) and after (1984) a severe drought. Their work emphasized the importance of the knowledge of the resilience of the fish communities in order to understand and manage the ecology of this diverse system. The total inundated area of the Phongolo Floodplain after a flood is approximately 10 265 ha, which decreases to 2 600 ha within six weeks into a series of discrete lakes and channels (Merron *et al.,* 1993a). During 1982 and 1984 a severe drought was recorded where less than 5% of the floodplain remained inundated. The results of Merron *et al.* (1993a) showed that of the original 35 species recorded before the drought, only 32 were collected during the drought and 30 during the post-drought survey. In addition, this study showed that flood-dependant species in the floodplain, such as *Labeo rosae,* did not appear to have bred during the drought as this species are known to synchronise their spawning with floods (Merron *et al.,* 1993a).

Concern was expressed regarding the importance of artificial floods and the timing thereof to maintain the fisheries in the floodplain. The dam has prevented the natural flow of the river and if not managed properly it may have a detrimental effect on fish species in the long term. The paucity of information on the natural inflows and released outflows and the ecological effects of these events were highlighted by Merron *et al.* (1993).

3.3 Results

3.3.1 Flow results

The historic data was obtained from DWA and the inflow of water was measured at the M'Hlati weir just upstream from where the Phongolo River flows into the Pongolapoort Dam and the releases were measured at the Jozini Weir about 1 km downstream of the dam wall (Figure 3.3).

The input column indicates which months the natural flow peaks. The high flow season is normally from late November to March, with 34% of the natural input occurring in December. The output column indicates which months the artificial floods peak, of which 41% are released during October with very few releases during December and January and then more releases during February (14%) and March (7%). The released floods do not correlate with the natural flow (input) into the impoundment.

The natural flow indicates that 69% of the natural flow occurs in summer (December to February). The artificial flow, however, indicates that 65% of the flood releases occur in spring (September to November) and only 17% during summer months.

Table 3.1: Comparison of the total inflow (natural flow) vs. output (artificial floods) from 1986 to 2013 in and out of the Pongolapoort Dam.

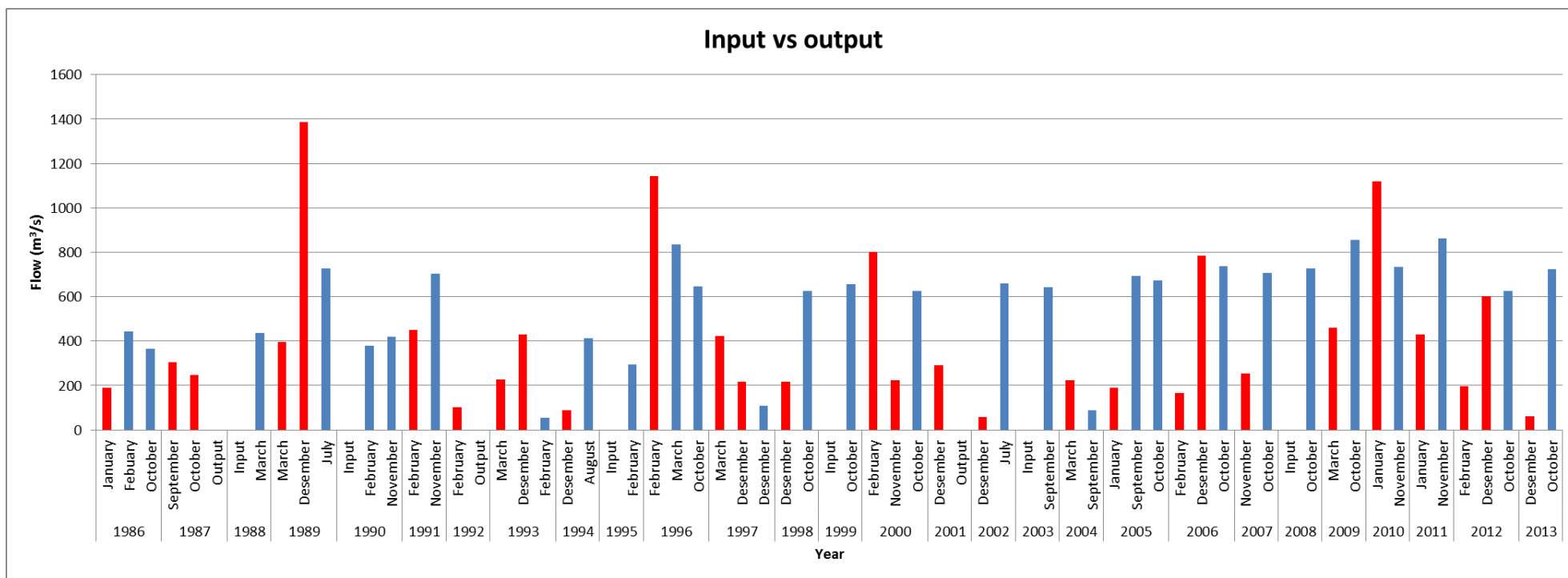| Input		Output	
Month	**Percentage**	**Month**	**Percentage**
January	14%	January	0
February	21%	February	14%
March	17 %	March	7%
April	0	April	0
May	0	May	0
June	0	June	0
July	0	July	7%
August	0	August	3%
September	3%	September	10%
October	3%	October	41%
November	7%	November	14%
December	34%	December	3%

Figure 3.3: Flow data of the Pongolapoort Dam.

Input (Red) indicates the recorded flow into the impoundment at the M'Hlati weir and output (Blue) indicates the flow out of the impoundment at the Jozini weir. The output is regarded as the artificial floods to simulate the natural floods. Empty input or output bars indicate that no data is available for that year.

3.3.2 Historic data vs. recent data

The study done by Merron *et al.* (1993a) on the changes in fish communities before, during and after drought was used to compare with the recent fish community (2012–2014). This work was followed up by Merron *et al.* (1993b, 1994a–e) in the early 1990s, where they did extensive work on the Phongolo Floodplain during 1993 and 1994, sampling most of the pans in the area. A total of six surveys were undertaken with three in high flow and three in low flow periods. The recent study consisted of five surveys of which two were in high flow and three were in low flow.

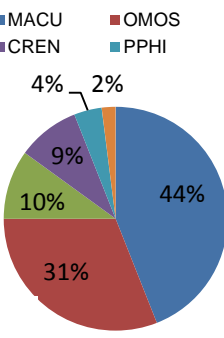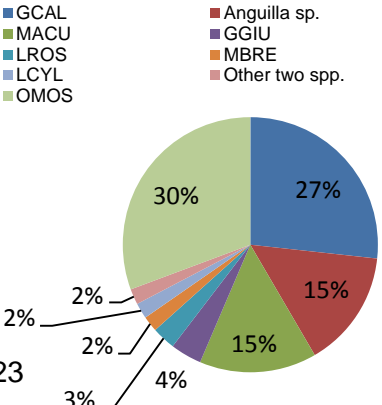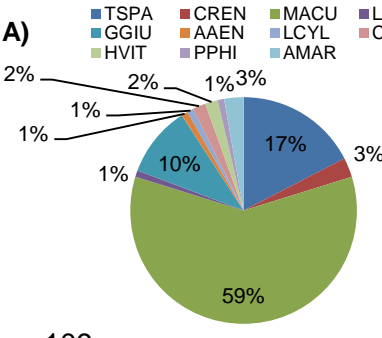Abbreviations used in the graphs are presented in the species list (Table 3.11).

During November 1993 at Site 6 (Nyamiti Pan) *O. mossambicus* (90%) was the dominant species followed by *Glossogobius sp.* (9%). A total of 925 individuals comprising five species were collected. During the November 2012 survey the dominant species was still *O. mossambicus* (65%) but the second dominant species was *Coptodon rendalli* (20%). A total of 208 individuals were caught at this site comprising five species (Table 3.2).

Table 3.2: Comparison of historic (1993) vs. recent (2012) community structures of fish at Site 6 during the November surveys (Low flow).

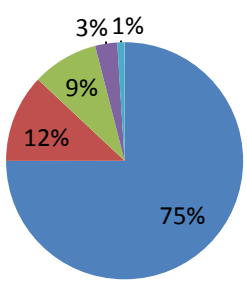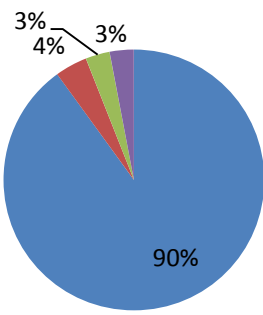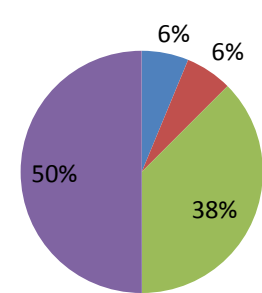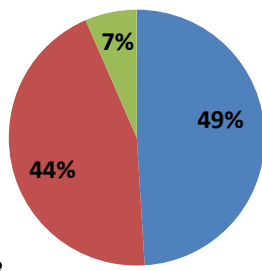|	November	
Site	**Historic**	**Recent**
Site 6 **Nyamiti Pan**	*n* = 925	*n* = 208
Method	Fish were collected using a 25 m seine net.	Fish were collected using a 35 m seine net.

Historic results represent two surveys conducted during 1993 (Table 3.3 A) and 1994 (Table 3.3 B). During 1993 (Table 3.3 A) the dominant species Site 1 was *Micralestes acutidens* (44%) followed by *O. mossambicus* (31%). However, during the 1994 (Table 3.3 B) survey *O. mossambicus* was the dominant species followed by *Glossogobius callidus.* A total of 499 individuals were caught comprising 12 species*.* During the 2013 survey *M. acutidens* (59%) was the dominant species followed by *Tilapia sparrmanii* (17%). A total of 109 individuals were caught comprising 11 species.

Table 3.3: Comparison of historic (1993/4) vs. recent (2013) community structures of fish during the April surveys (High flow).

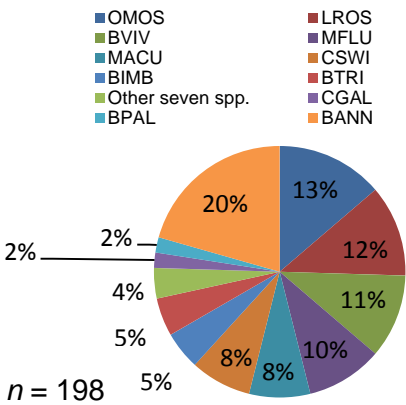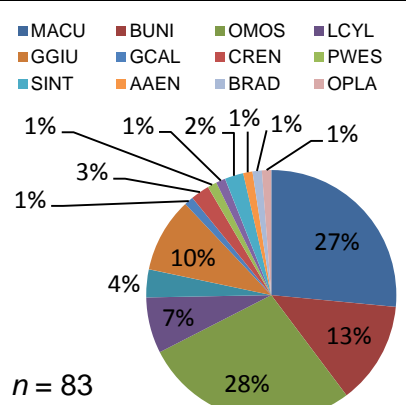|	April	
Site	**Historic**	**Recent**
Site1 **Phongolo River**	A) (pie chart) legend: MACU, OMOS, MBRE, CREN, PPHI, GCAL — 44%, 31%, 10%, 9%, 4%, 2%; *n* = 176 B) (pie chart) legend: GCAL, MACU, LROS, LCYL, OMOS, Anguilla sp., GGIU, MBRE, Other two spp. — 27%, 15%, 15%, 4%, 3%, 2%, 2%, 2%, 30%; *n* = 323	A) (pie chart) legend: TSPA, CREN, MACU, LMOL, GGIU, AAEN, LCYL, CGAR, HVIT, PPHI, AMAR — 17%, 3%, 59%, 10%, 1%, 1%, 1%, 2%, 1%, 2%, 3%; *n* = 109
Method	**A)** Fish were collected using a minnow seine net (1994) **B)** Fish were collected using rotenone (1994).	Fish were collected using a minnow seine and electrofishing.

58

During the 1994 survey two areas in Nyamiti Pan were sampled, a vegetated (Table 3.4 A) and non-vegetated area (Table 3.4 B). In both instances the dominant species at Site 6 were *O. mossambicus* (75% in vegetated area; 90% in non-vegetated area), followed by *G. callidus* (12% in vegetated area; 4% in non-vegetated area). A total of 532 individuals were caught comprising 4 species. Recent results indicate that during 2013 (Table 3.4 A) this pan was dominated by *C. rendalli* (50%) followed by *O. mossambicus* (38%). During 2014 (Table 3.4 B) *O. mossambicus* (49%) dominated the pan closely followed by *C. rendalli* (44%). A total of 169 individuals were caught comprising 3 species.

Table 3.4: Comparison of historic (1993/4) vs. recent (2013/14) community structures of fish during the April surveys (High flow).

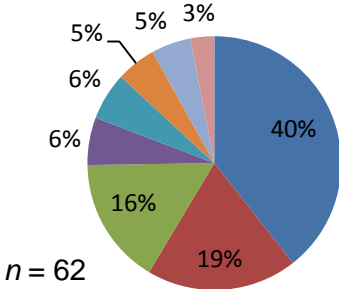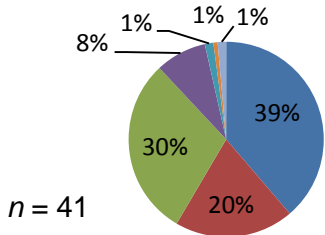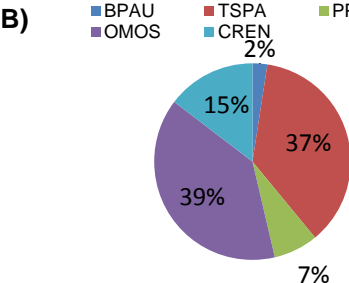| Site	Historic	Recent
Site 6 **Nyamiti Pan**	**A)** OMOS GCAL CREN GGIU BIMB 3% 1% 9% 12% 75% *n* = 179 **B)** OMOS GCAL CREN Other three spp. 3% 4% 3% 90% *n* = 353	**A)** HVIT SINT OMOS CREN 6% 6% 50% 38% *n* = 109 **B)** OMOS CREN HVIT 7% 49% 44% *n* = 153
Method	**A)** Fish were collected using a 25 m seine net in a vegetated area, **B)** Fish were collected using a 25 m seine net in a non-vegetated area.	**A)** Fish were collected using a 35 m seine net (2013), **B)** Fish were collected using a 35 m seine net (2014).

During the 1994 survey Site 11(Table 3.5) was dominated by *B. annectens* (21%) followed by *O. mossambicus* (14%). A total of 198 individuals were caught comprising 17 species. During 2013 Site 11 was dominated by *O. mossambicus* (28%) closely followed by *M. acutidens* (27%). A total of 83 individuals were caught comprising 14 species (Table 3.5).

Table 3.5: Comparison of historic (1993/4) vs. recent (2013/14) community structures of fish during the April surveys (High flow)

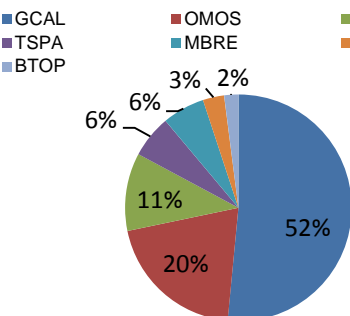| April		
Site	**Historic**	**Recent**
Site11 **Usutu River**		
Method	Fish were collected using a 25 m seine net and a minnow seine net.	Fish were collected using a minnow seine and electrofishing.
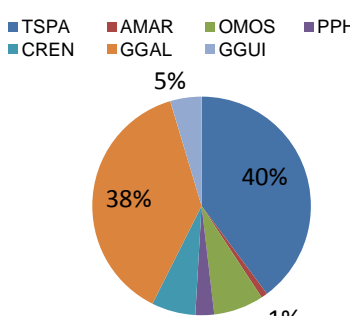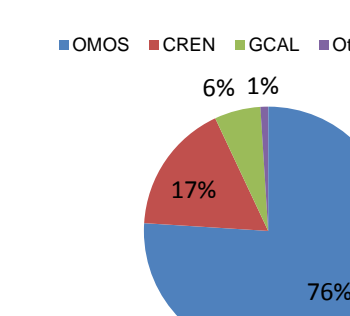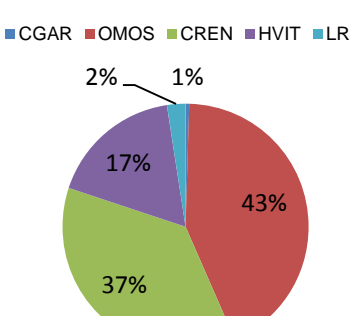
During 1994 Site 12 (Table 3.6) was dominated by the smaller fish species such as *B. annectens* (40%) and *P. philander* (19%). A total of 62 individuals were caught comprising 9 species. During 2013 (Table 3.6 A) Site 12 was dominated by *C. rendalli* (50%) followed by *T. sparrmanii* (30%) with a total of 142 individuals caught comprising 7 species. On return in 2014 (Table 3.6 B) Site 12 was dominated by *O. mossambicus* followed by *T. sparrmanii* (37%). A total of 41 individuals were caught comprising 5 species.

Table 3.6: Comparison of historic (1994) vs. recent (2013/14) community structures of fish during the April surveys (High flow).

Site	Historic	Recent
Site 12 **Nama- neni Pan**	Fish were collected using a minnow seine net.	**A)** Fish were collected using a 35 m seine net (2013), **B)** Fish were collected using a 35 m seine net (2014).
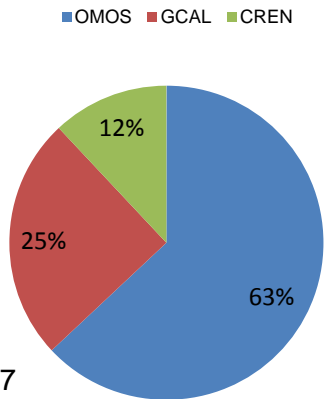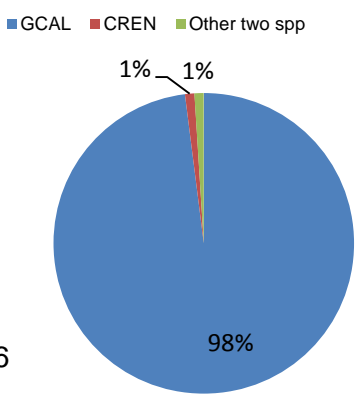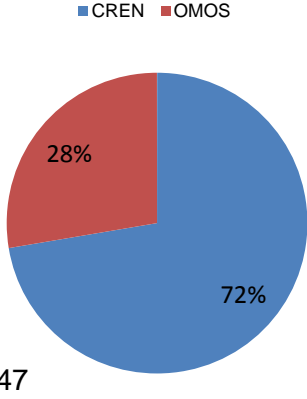
During the July survey (Table 3.7) of 1994 Site 1 was largely populated by *G. callidus* (52%) followed by *O. mossambicus* (20%). A total of 173 individuals were caught comprising 8 species. During 2013 Site 1 was dominated by *T. sparrmanii* (40%) followed by *G. callidus* (38%). A total of 108 individuals were caught comprising 7 species. Site 6 was dominated by *O. mossambicus* (76%) during the 1993 survey followed by *T. rendalli* (17%). A total of 381 individuals were caught comprising 5 species. The same species dominated this site during the 2013 survey with *O. mossambicus* (43%) and *C. rendalli* (37%). A total of 412 individuals were caught comprising 5 species (Table 3.7).

Table 3.7: Comparison of historic (1994) vs. recent (2013) community structures of fish during the July surveys (Low flow).

	July	
Site	**Historic**	**Recent**
Site1 **Phongolo River**	GCAL, OMOS, MACU, TSPA, MBRE, Other two spp., BTOP — 52%, 20%, 11%, 6%, 6%, 3%, 2% — *n* = 173	TSPA, AMAR, OMOS, PPHI, CREN, GGAL, GGUI — 40%, 38%, 6%, 3%, 7%, 1%, 5% — *n* = 108
Method	Fish were collected using a minnow seine net electrofishing and rotenone.	Fish were collected using a minnow seine and electrofishing.
Site 6 **Nyamiti Pan**	OMOS, CREN, GCAL, Other two spp. — 76%, 17%, 6%, 1% — *n* = 381	CGAR, OMOS, CREN, HVIT, LROS — 43%, 37%, 17%, 2%, 1% — *n* = 412
Method	Fish were collected using a 25 m seine net.	Fish were collected using a 35 m seine net.
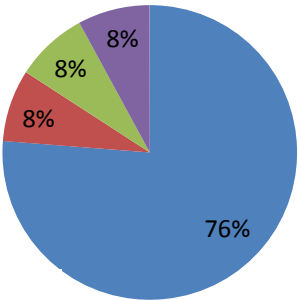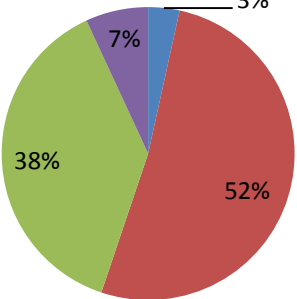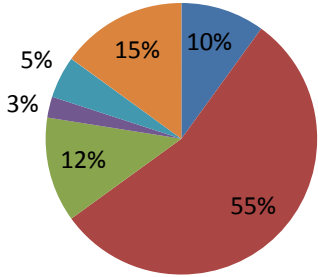
During September 1993 Merron *et al.* (1994d) sampled most of the sites of their study twice. One sampling effort was made before a scheduled flood release and another just after the flood release. Before the flood release Site 6 was dominated by *O. mossambicus* (67%) followed by *G. callidus* (25%) with the only other species found being C*. rendalli* (12%) (Table 3.8 A) and a total of 677 individuals were caught comprising 3 species. After the flood release (Table 3.8 B) the dominant species was *G. callidus* (98%) and *T. rendalli* (1%). A total of 566 individuals were caught comprising 4 species. During the 2013 survey this site was dominated by *C. rendalli* (72%) and *O. mossambicus* (28%) and these were the only two species caught with a total of 47 fish.

Table 3.8: Comparison of historic (1994) vs. recent (2013) community structures of fish during the September surveys (Low flow).

	September	
Site	**Historic**	**Recent**
Site 6 **Nyamiti Pan**	A) ■OMOS ■GCAL ■CREN 12% 25% 63% *n* = 677 B) ■GCAL ■CREN ■Other two spp 1% 1% *n* = 566 98%	■CREN ■OMOS 28% 72% *n* = 47
Method	A) Pre-flood sampling where fish were collected using a 25 m seine net B) Post-flood sampling where fish were collected using a 25 m seine net	Fish were collected using a 35 m seine net

63

Sites 12 and 13 were dry before the flood release in 1994 and could not be sampled. After the flood release, however, these two sites were connected and the dominated species found was *P. philander* (77%). A total of 13 individuals were caught comprising 4 species (Table 3.9). During the September 2013 survey these two sites were not connected. Site 12 (Table 3.9 A) was dominated by *C. rendalli* (52%) followed by *T. sparrmanii* (38%) with a total of 29 individuals comprising 4 species caught. Site 13 (Table 3.9 B) was dominated by *B. trimaculatus* (55%) followed by *B. annectens* (15%) with a total of 40 individuals comprising 6 species caught.

Table 3.9: Comparison of historic (1994) vs. recent (2013) community structures of fish during the September surveys (Low flow).

Site	Historic	Recent
Site 12/13 **Nomaneni Pan** **/** **Bumbe Pan**	*n* = 13	*n* = 29 *n* = 40
Method	Sites 12 and 13 were connected after a flood release; fish were collected using minnow seine nets.	**A)** Fish were collected using a 35 m seine net and minnow seine nets (Site 12), **B)** Fish were collected using a minnow seine net (Site 13).

64

3.3.3 Recent results from additional sites

3.3.3.1 November 2012 (Low flow)

Site 7 (Phongolo River) was dominated by two species, *P. wesselsi* (27%) and *M. macrolepidotus* (27%) (Table 3.10). A total of 277 individuals were caught comprising 10 species. Site 8 (isolated pan) was largely dominated by *O. mossambicus* (72%) followed by *B. toppini* (8%). A total of 745 individuals were caught comprising 9 species. Site 10 (outflow of Nyamiti Pan) was dominated by *B. toppini* (54%) followed by *S. zambezensis* (22%) (Table 3.10). A total of 291 individuals were caught comprising 10 species.

3.3.3.2 April 2013 (High flow)

Site 2 (Upper Phongolo River) was dominated by two species, *M. acutidens* (29%) and *T. sparrmanii* (27%) (Table 3.10). A total of 100 individuals were caught comprising 9 species. Site 4 (Middle Ngwavuma River) was largely dominated by *B. unitaeniatus* (51%) followed by *O. mossambicus* (10%) and *C. paratus* (10%) (Table 3.10). A total of 91 individuals were caught comprising 9 species. Site 5 (Lower Ngwavuma River) was dominated by *B. unitaeniatus* (51%) followed by *L. cylindricus* (19%). A total of 97 individuals were caught comprising 11 species. Site 7 (Phongolo River) was dominated by *P. wesselsi* (38%) followed by *B. unitaeniatus* (28%) (Table 3.10). A total of 204 individuals were caught comprising 12 species. Site 9 (Isolated pool) was dominated by *O. mossambicus* (55%) followed by *C. carpio* (19%) (Table 3.10). A total of 110 individuals were caught comprising 8 species. Site 10 (Outflow of Nyamiti Pan) was dominated by *Barbus afrohamiltoni* (26%) followed by *Glossogobius giurus* (22%) (Table 3.10). A total of 142 individuals were caught comprising 17 species.

3.3.3.3 July 2013 (Low flow)

Site 2 (Upper Phongolo River) was dominated by *M. acutidens* (68%) followed by *L. cylindricus* (8%) (Table 3.10). A total of 106 individuals were caught comprising 11 species. Site 3 (Upper Ngwavuma River) was used as a reference site for the Ngwavuma River and was only sampled once. This site was dominated by *B. unitaeniatus* (39%) followed by *L. cylindricus* (14%) (Table 3.10). A total of 123 individuals were caught comprising 9 species. Site 4 (Middle Ngwavuma River) was dominated by *B. unitaeniatus* (36%) closely followed by *O. mossambicus* (35%) (Table 3.10). A total of 119 individuals were caught comprising 7 species. Site 5 (Lower Ngwavuma River) was dominated by *B. unitaeniatus* (51%) followed by *G. callidus* (22%) (Table 3.10). A total of 83 individuals were caught comprising 11 species. Site 7 (Phongolo River) was dominated by *B. unitaeniatus* (47%) followed by *L. cylindricus* (18%) (Table 3.10). A total of 131 individuals were caught comprising 13 species.

Site 10 (Outflow of Nyamiti Pan) was dominated by *B. toppini* (71%) followed by *O. mossambicus* (12%) (Table 3.10). A total of 59 individuals were caught comprising 9 species.

3.3.3.4 September 2013 (Low flow)

Site 7 (Phongolo River) was dominated by *O. mossambicus* (39%) followed by *B. afrohamiltoni* (31%) (Table 3.10). A total of 142 individuals were caught comprising 10 species. Site 10 (Outflow of Nyamiti Pan) was dominated by *S. intermedius* (58%) followed by *O. mossambicus* (25%) (Table 3.10). A total of 466 individuals were caught comprising 14 species.

3.3.3.5 April 2014 (High flow)

Site 7 (Phongolo River) was dominated by *S. intermedius* (21%), closely followed by *C. gariepinus* (20%) (Table 3.10). A total of 39 individuals were caught comprising 8 species. Site 9 (Isolated pool) was dominated by *H. vittatus* (57%) followed by *Brycinus imberi* (17%) (Table 3.10). A total of 23 individuals were caught comprising 6 species.

Table 3.10: Recent community structures results from different sites in the Phongolo Floodplain collected during five surveys from November 2012 to April 2014.

Site	November 2012	April 2013	July 2013	September 2013	April 2014
Site 2		*n* = 100	*n* = 106		
		Fish were collected using a minnow seine and electrofishing	Fish were collected using a minnow seine and electrofishing		
Site 3			*n* = 123		
			Fish were collected using electrofishing		

April 2013 pie chart legend: HVIT, CREN, GGIU, LCYL, MACU, TSPA, BTRI, LMAR, CGAR, AMAR, SZAM
April 2013 pie values: 9%, 3%, 15%, 6%, 29%, 29%, 1%, 3%, 2%, 2%, 1%

July 2013 (Site 2) pie chart legend: GGIU, OMOS, GCAL, LCYL, GPAR, AMAR, BIMB, MACU, BTRI, BUNI, TSPA
July 2013 (Site 2) pie values: 2%, 3%, 6%, 8%, 3%, 1%, 1%, 68%, 4%, 3%, 1%

July 2013 (Site 3) pie chart legend: OMOS, BTRI, BAFR, BUNI, LCYL, LMOL, CPAR, CSWI, CGAR
July 2013 (Site 3) pie values: 10%, 10%, 8%, 39%, 14%, 10%, 5%, 2%, 2%

Table 3.10 (continued): Recent community structures results from different sites in the Phongolo Floodplain collected during five surveys from November 2012 to April 2014.

Site	November 2012	April 2013	July 2013	September 2013	April 2014
Site 4		*n* = 91	*n* = 119		
		Fish were collected using electrofishing	Fish were collected using electrofishing		
Site 5		*n* = 97	*n* = 83		
		Fish were collected using electrofishing	Fish were collected using electrofishing		

Table 3.10 (continued): Recent community structures results from different sites in the Phongolo Floodplain collected during five surveys from November 2012 to April 2014.

Site	November 2012	April 2013	July 2013	September 2013	April 2014
Site 7	n = 277	n = 204	n = 131	n = 142	n = 39
	Fish were collected using fyke nets, minnow seine net and electrofishing	Fish were collected using electrofishing	Fish were collected using electrofishing and fyke nets	Fish were collected using fyke nets	Fish were collected using fyke nets
Site 8	n = 745				
	Fish were collected using a 35 m seine net				

Table 3.10 (continued): Recent community structures results from different sites in the Phongolo Floodplain collected during five surveys from November 2012 to April 2014.
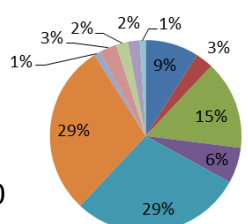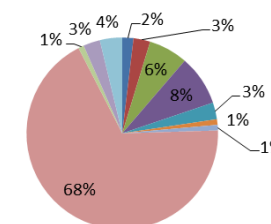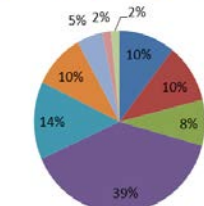
Site	November 2012	April 2013	July 2013	September 2013	April 2014
Site 9		n = 110			n = 23
		Fish were collected using a 35 m seine net			Fish were collected using a 35 m seine net
Site 10	n = 291	n = 142	n = 59	n = 466	
	Fish were collected using electrofishing	Fish were collected using electrofishing and a minnow seine net	Fish were collected using electrofishing	Fish were collected using a 35 m seine net.	

3.3.4 Statistical analysis
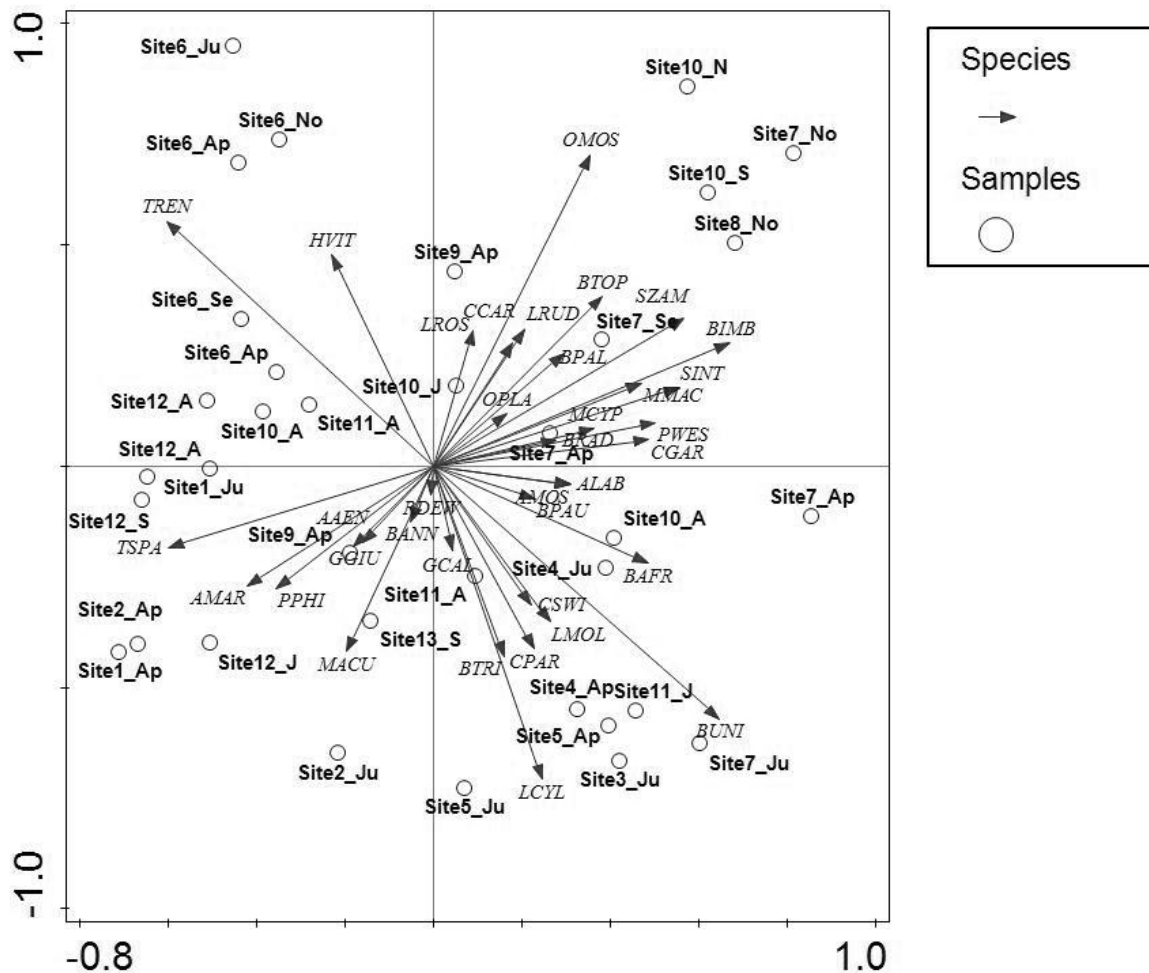
Figure 3.4: Principle Component Analysis (PCA) bi-plot of species at different sites from five different surveys (2012–2014).

Axes one and two explain a cumulative variation of 37.45%, and axes three and four a cumulative 23.02% of variance. The total explained variance is 60.94%. Species that prefer slow-flowing water are grouped together, for instance, *C. rendalli, O. mossambicus* and *H. vittatus* prefer Site 6, and large numbers of these species were caught at this site. The above-mentioned species all seem to prefer the pans above the river sites. Smaller species such as *B. unitaeniatus*, *B. afrohamiltoni* and *B. trimaculatus* all seem to prefer the river sites and are all grouped close to Sites 3, 4, 5 and 7 (all river sites). This is a clear indication that certain species prefer certain habitat types, whether it is a river or more stagnant water bodies such as pans.

Figure 3.5: Redundancy Analysis (RDA) tri-plot of environmental variables, species and sites from five different surveys (2012–2014).

Axes one and two explain a cumulative variation of 30.85% and axes three and four a cumulative 29.95% of variance. The total explained variance is 60.8%. A distinct difference can be seen between the species that occur in or prefer high flow conditions compared to those that prefer or occur in low flow conditions. High flow conditions strongly correlate with higher levels of dissolved oxygen. Sites 1, 2, 4 and 11 are all river sites and are grouped together close to the high flow conditions. High flow surveys strongly correlated to the high flow environmental variables, e.g. high dissolved oxygen levels.

Pan sites are all closely grouped near the low flow conditions and correlate with higher temperatures, higher conductivity and more Total Dissolved Solids (TDS). Species like *O. mossambicus* and *C. rendalli* were found in large numbers at these sites.

3.3.5 Species diversity of the Phongolo Floodplain, 1974–2014

During the historic study done by Merron *et al.* (1993a), 35 species were recorded in this system over a period of two years (1974–1976). During the severe drought of 1983 a total of 32 out of the original 35 species were collected and by 1984 only 30. During the recent study (2012–2014), a total of 35 species were found again; however, these 35 species were not the same species originally found in 1976. The historic species found in 1974–1984 that were not found during this study include: *A. bicolor bicolor, L. congoro, L. marequensis, M. brevianalis, C. ngamensis* and *N. orthonotus.* Species that were found during the recent survey that were not recorded during the 1974–1984 surveys include: *A. aeneofuscus, G. callidus, O. placidus, M. cyprinoides, C. carpio* and *B. pallidus.*

Table 3.11: Comparative species list of the fishes collected from of the Lower Phongolo River and floodplain (Data from Merron *et al.* 1993a, b, 1994a–e; present study). Names in brackets refer to previous nomenclature.

Species	1974	1983	1984	1993-4	2012-14
Alestidae					
Brycinus imberi (lateralis)	x	x	x	x	x
Hydrocynus vittatus	x	x	x	x	x
Micralestes acutidens	x	x	x	x	x
Anguiliidae					
Anguilla bengalensis labiata (nebulosa)	x	x		x	x
Anguilla bicolor bicolor	x	x		x	x
Anguilla marmorata	x	x		x	x
Anguilla mossambica	x		x	x	x
Cichlidae					
Coptodon rendalli (Tilapia rendalli)	x	x	x	x	x
Oreochromis mossambicus	x	x	x	x	x
Oreochromis placidus					x
Pseudocrenilabrus philander	x	x	x	x	x
Tilapia sparrmanii	x	x	x	x	x
Clariidae					
Clarias gariepinus	x	x	x	x	x
Clarias ngamensis	x	x	x	x	

Table 3.12: Continued

Species	1974	1983	1984	1993-4	2012-14
Cyprinidae					
Barbus afrohamiltoni	x	x	x	x	x
Barbus annectens	x	x	x	x	x
Barbus pallidus				x	x
Barbus paludinosus	x	x	x	x	x
Barbus radiatus	x	x	x	x	x
Barbus toppini	x	x	x	x	x
Barbus trimaculatus	x	x	x	x	x
Barbus unitaeniatus				x	x
Barbus viviparus	x	x	x	x	
*Cyprinus carpio**				x	x
Labeo congoro	x	x	x	x	
Labeo cylindricus	x	x	x	x	x
Labeo molybdinus	x	x	x	x	x
Labeo rosae	x	x	x	x	x
Labeobarbus marequensis	x	x			
Mesobola brevianalis	x	x	x	x	
Opsaridium peringueyi (zambezense)				x	
Cyprinodontidae					
Nothobranchius orthonotus	x			x	x
Gobiidae					
Awaous aeneofuscus				x	x
Glossogobius callidus				x	x
Glossogobius giuris	x	x	x	x	x
Redigobius dewalli	x	x	x	x	x
Megalopidae					
Megalops cyprinoides				x	x
Mochokidae					
Chiloglanis paratus	x		x	x	x
Chiloglanis swierstrai	x	x	x	x	x
Synodontis zambezensis	x	x	x	x	x
Mormyridae					
Marcusenius macrolepidotus	x	x	x	x	x
Petrocephalus wesselsi (catostoma)	x	x	x	x	x
Schilbeidae					
Schilbe intermedius	x	x	x	x	x
Syngnathidae					
Microphis fluviatilis				x	
Total no. of species	35	32	30	42	37

* Introduced species

74

3.4 Discussion

3.4.1 Flow regime

Flow data from 1986 to 2013 suggest that, based on the flow into the impoundment, the natural flow of the river peaks between the summer months of December and February. However, the flood releases that are supposed to simulate the natural flow of the river are released mainly in the months of September and November and again in February and March. In other words, the natural high flow of the summer months has now been changed to early spring and late summer, with the majority of these floods being in spring (October). The economically important fish such as *L. rosae, C. rendalli, H. vittatus, C. gariepinus* and *S. zambesensis* spawn in the summer months (Skelton, 2001) and are dependent on the summer floods that are now interrupted. With the flow being altered in such a way that there are no available habitats for some of these species to breed, this can cause certain species to disappear from the system or be replaced by other faster colonizing species such as *B. afrohamiltoni* (Merron *et al.,* 1985).

Oreochromis mossambicus is not dependent on the summer floods for spawning (Bruton, 1979, Merron *et al.* 1993) and is tolerant to a wide range of ecological and physiological conditions (Bruton, 1979; Merron *et al.,* 1993; Weyl & Hecht 1998; Skelton, 2001). This species also has the ability to tend towards an altricial life history where, if the fish are exposed to harsh and unstable environments (flood regime) they become sexually mature at a smaller size (Weyl & Hecht 1998). The above-mentioned facts regarding *O. mossambicus* may be the reason why this species is one of the fastest colonizing and most successful species in the Phongolo Floodplain. *Barbus afrohamiltoni* does not depend on floods for spawning and is relatively tolerant to extremely low water levels (Merron *et al.*, 1993a). *Glossogobius callidus* is a widespread species throughout the Phongolo Floodplain and is tolerant to a wide range of environmental conditions (Merron *et al.*, 1993). Merron *et al.* (1993) saw a similar trend with the above three species colonizing large parts of the river during the drought of 1982 to 1984.

3.4.2 Historic data vs. recent data

The November survey (low flow) of 1993 revealed that Nyamiti Pan (Site 1) is largely populated by *O. mossambicus* and *G. callidus.* A staggering 925 fish were caught with one pull of a 25 m seine net. During 2012 only 208 fish were caught with 8 pulls of a 35 m seine net. *Oreochromis mossambicus* remained the dominant species in the pan but the *H. vittatus* population increased

dramatically from < 1% in 1993 to 12% in 2012. *Coptodon rendalli* also increased from 1% to 20%.

Historic data from April 1994 revealed that there was a large number of *M. acutidens, O, mossambicus, G. callidus* and *Anguilla sp.* present at Site 1 (Phongolo River) (Merron *et al.* 1994b). The situation shifted, with *O. mossambicus* and *G. callidus* now dominant. *Tilapia sparrmanii* has now established in the vegetated areas at this site. Of the original 12 species recorded at this site during high flow, only 11 were collected during the recent survey. *Mesobola brevianalis* was not found at this site and this might be attributed to the irregular floods of previous years. The total number of fish also decreased from 1994 to 2013, but this can be attributed to the fact that during the 1994 survey rotenone was used.

Site 6 (Nyamiti Pan) was historically dominated by *O. mossambicus* in both vegetated and non-vegetated areas of the pan. During the 2013 and 2014 surveys *O. mossambicus* still dominated the system, but an increase in the number of *C. rendalli* was observed. The number *H. vittatus* also increased from 1994 but remained the same between 2013 and 2014. The total number of fish in Nyamiti Pan decreased. During the historic survey a single haul of a 25 m seine net caught a total of 353 fish, compared to the 8 hauls of a 35 m seine net catching only 156 fish in 2014. The decrease in the number of *O. mossambicus* may be attributed the high infestation of parasites, which prefer these species to the other cichlid, *C. rendalli*, in the pan (see Chapter 5)

Site 11 (Usutu River) during the 1994 survey had 17 different species and of those the most abundant were *Chiloglanis swierstrai, Barbus viviparus* and *Microphis fluviatilis*, none of which were found during the 2013 survey. Of these species, *M. fluviatilis* is of estuarine origin and is normally not found so far inland (Skelton 2001). During the 2013 survey *O. placidus* was found, which were not found in previous surveys.

Site 12 (Nomaneni Pan) was historically dominated by small fish species such as *B. annectens* and *Pseudocrenilabrus philander*. This remained the same during the 2013–2014 surveys with the exception of *T. sparrmanii* and *O. mossambicus*. Only small specimens with a TL ranging between 30 and 60 mm of the two latter species were collected. The number of fish decreased from 142 (2013) to 42 (2014). The reason there are no large fish in this pan may attributed to the local people using the fish from this pan as their source of protein. Community members have free access to the pan and are allowed to fish in this pan using a wide variety of methods (Figure 3.6). The impact of these methods may have an effect on the fish community structure

in these pans as there are no size limits on the fish caught within these pan. This results in the removal of juveniles from these water bodies.

Figure 3.6 Community members using traditional fishing methods to catch fish.

Traditional fishing methods include:

isiFonya: This is the most spectacular method and involves the entire community. A line of people is formed right across the pan, each wielding a basket. Fish are then simultaneously driven toward the shallows by the thrusting of baskets through the water (Heeg & Breen, 1982; Merron *et al.,* 1993b). These baskets are made of packed sticks closely stacked together, forming a 'mesh size' of 10 mm. Fish are extracted at the apex of the basket.

Mona-basket: This can be best described as a trap. It is made out of reeds and placed in a carefully constructed reed fence within a water course. This is the preferred method of catching fish during floods when fish are migrating (Heeg & Breen, 1982). This method can be regarded as the modern day fyke net.

Seine nets: Primitive seine nets include long bundles of reeds pushed through the water, or pieces of fabric and shade cloth dragged through the water (Heeg & Breen,1982; pers. obs.).

Fishing: Modern techniques like fishing with rod and reel as well as hand lines are also often used (pers. obs.).

The historic data shows a change in dominance at Site 1 (Phongolo River) during the low flow survey, with the dominant species during the high flow survey, *O. mossambicus*, being replaced with *G. callidus*. The number of fish also declined drastically from 499 during high flow to 173

during low flow, using the same efforts. Recent results indicate that the dominant species during the 2013 high flow season is now replaced with *T. sparrmanii,* and that the numbers of the historically dominant species, *G. callidus*, have increased significantly and that this species is dominant again during the low flow. Although the number of fish has declined when compared to historic data, the number of fish during recent low flow and high flow has remained stable. The reason for the high numbers caught during the historic survey was the use of rotenone.

During the low flow survey of June 1994 at Site 6 (Nyamiti Pan), *O. mossambicus* remained the dominant species in this pan, but the numbers of *C. rendalli* increased significantly. When compared to the recent result of the pan, *O. mossambicus* remained the dominant species in this pan but the number of *C. rendalli* had increased even more when compared to the high flow season. Although more fish were caught during low flow in Nyamiti Pan, historic results indicate that there were more fish in the pan during 1994, because only 412 fish were caught with 6 hauls of a 35 m seine net, compared to 1994 when a total of 381 fish were caught in a single haul of a 25 m seine net. This can be attributed to a number of factors, including parasite infestation, increased numbers of *H. vittatus* preying on *O. mossambicus* as well as a large number of crocodiles (*Crocodylus niloticus*). Ndumo Game Reserve supports one of South Africa's largest wild crocodile populations and after reaching a length of 120 cm they mainly feed on fish (Carverley & Downs, in press).

During the September survey (low flow) of 1994, Merron *et al.* (1994d) did two surveys, one before a flood release and a second just after the flood release. The community structure of Site 6 (Nyamiti Pan) remained stable compared to the previous low flow survey (June 1994), although the number of fish almost doubled. What raised concern is that after the flood release in August 1994 the large number of *O. mossambicus* and *C. rendalli* from the pan disappeared and *G. callidus* dominated the pan with 98% of the species composition. The number of fish remained high, however, with a total of 566. The cause of this change in community structure can possibly be attributed to the fact that the floods of 1994 could have dispersed the *O. mossambicus* and *C. rendalli* from the pan into the river below and replaced them with the *G. callidus* that were present in pools and pans further upstream.

Results from the September 2013 survey indicated that the pan is dominated by *C. rendalli* during low flow and that the numbers of fish are still declining, with only 47 fish caught with 3 hauls of a 35 m seine net.

Changes were noticed in community structures when historic data was compared to recent data. The absence of sensitive species like *M. brevianalis*, which prefers well aerated, open flowing water, was noticed. This species breeds in early summer. It is possible that the flow alterations and the early spring flood releases of recent years have caused this species to be replaced by faster colonizing species, or that the lack of habitat during the summer months prohibits their recruitment.

With regards to the additional sites sampled during 2012 to 2014, only a selected few will be discussed. Site 2 (Phongolo River) was sampled during the high flow (April 2013) and the low flow (July 2013). During both surveys *M. acutidens* was the dominant species at this site. Species that were present during high flow but not during low flow included; *C. rendalli, L. cylindricus, C. gariepinus* and *S. zambezensis*, all of which prefer either riffles or backwater pools for breeding or as their preferred habitat (Skelton, 2001). With the receding water level during the low flow, none of these species were caught and this may be attributed to loss of habitat due to the lower water level. During the low flow survey (July 2013), this site was still dominated by *M. acutidens,* but the composition of the rest of the community structure has changed. Species with a wide range of environmental tolerances were now present at this site, like *G. callidus, G. giurus* and *O. mossambicus* (Merron *et al.,* 1993; Skelton, 2001). This occurrence was also noticed by Merron *et al.* (1985) with the absence of *N. orthonotus*, which was replaced with more rapidly colonizing species like *B. toppini* and *B. paludinosus*.

The fish community structure of Site 4 did not change drastically between high flow and low flow. On both occasions *B. unitaeniatus* and *B. afrohamiltoni*, which are both rapidly colonizing species (Merron *et al.*, 1993), dominated this site, which could mean that they are replacing more sensitive species. The absence of sensitive species such as *M. acutidens, B. imberi* and *C. paratus,* may be a consequence of poor water quality due to human impacts, as this was one of the most impacted sites (Kleynhans, 2007). Extensive sand abstraction and washing of clothes and vehicles were present at this site on both occasions, leading to extensive loss of habitat. A similar trend was noticed at Site 5 (Lower Ngwavuma River), but the impacts differed in that they were not directly caused by humans but rather erosion due to strong flows at this site as a result of large pipes that channel the water underneath a bridge. The erosion is facilitated by wood abstraction in the riparian zone.

The fish community structure of fish at Site 7 (Phongolo River) did not differ between the low flow surveys, with the exception of one or two species at certain surveys. However, the community structure during high flow changed, with 9 species not present. These species were: *B. pallidus, B. toppini, L. cylindricus, B. trimaculatus, M. acutidens, G. callidus L. molybdinus, L. rosae* and *G. giurus*. These species might have been washed away by floods or migrated further downstream due to habitat loss. Conversely, three species were found in high flow that was not present during low flow: *B. unitaeniatus, A. mossambicus* and *Megalops cyprinoides*, which might have been washed downstream from further up in the river.

Sites 8 and 9 were isolated pools that fill with water during high flow but dry up during low flow. During the November 2012 survey, Site 8 was still filled from the October 2012 flood release and acted as a refuge for *O. mossambicus* and several *Barbus* species, and a large number of juveniles were caught in minnow seine nets in this pan. Unfortunately, large numbers of *C. carpio* juveniles were also caught in the minnow seine nets, suggesting that they also use the pans as breeding sites. The same trend was noticed during high flow when these pans were filled again during April 2013, with large numbers of *O. mossambicus* and *C. carpio* in Site 9. It seems therefore that both these species will utilize seasonal pans for breeding (Skelton, 2001). This is a cause of concern, because there are two likely situations that may happen. Firstly, the fish will breed in these pans and restock the river. This has a positive effect on the *O. mossambicus* population in the river, but a negative effect with regard to the number *of C. carpio* numbers in the Phongolo River. Secondly, both these species will breed in these seasonal pans but they will dry up or will be cut off from the river with receding water levels during low flow. This will positively affect the numbers of *C. carpio* in the river, but negatively affect the number of *O. mossambicus* in this system. If this is the case for all or most of the pans in the Phongolo Floodplain, it may benefit the local communities that are situated around most of the pans in the floodplain. The local population remove 400 tonnes of fish per annum (Heeg & Breen, 1982) and this may help with the control of *C. carpio* numbers. What is concerning is the fact that there are large numbers of *C. carpio* in the Ndumo Game Reserve that have no direct human impacts or fish exploitation, and this serves as a possible refuge for these alien invasive species.

Figure 3.7: Photos of *Cyprinus carpio* caught at various pans within the Ndumo Game Reserve.

Site 10 (Outflow of Nyamiti Pan) has produced the most species, which emphasizes the importance of this pan in the conservation of the fish species of the lower Phongolo Floodplain. A combined total of 22 out of the possible 42 species recorded in the Phongolo Floodplain were caught at this site during high and low flow. During low flow this site was dominated by *B. toppini* and *S. intermedius.* The community structure during the low flow surveys had a higher combined diversity when compared to the diversity of the high flow. A total of four species, *B. toppini, G. callidus, O. placidus, B. radiatus* and *L. cylindricus* were found during the low flow, but were not present during high flow. This may be due to the causeway that traps certain species in Nyamiti Pan during low flow. Conversely, three species that were not present during low flow were caught at this site during high flow; these species include: *C. gariepinus, M. macrolepidotus* and *P. wesselsi,* all of which were recorded in large numbers upstream during previous surveys. It may be that these species were transferred downstream into Nyamiti Pan during high flow and ended up in the pan due to the backflow into the pan (see Chapter 2).

It is evident that the fish community structures change during the high flow season, benefiting some species, but negatively influencing others. The same trend was noticed during the mid-1970s to mid-1980s (Merron *et al.,* 1993a) and again in the mid-1990s (Merron *et al.,* 1993b, 1994a–e). Merron *et al.* (1993) also concluded that the dominant species of 1984 (after the severe drought) presumably originated from the conserved pans in Ndumo Game Reserve, which strongly supports the theory of fish that use Nyamiti Pan as a refuge for breeding purposes. And if this is the case for Nyamiti Pan, potamodromous fish will also seek out isolated pools within the reserve to breed, as was the case at Site 8 during the November (2012) survey.

3.4.3 Statistical analysis

The Principal Component Analysis (PCA) bi-plot indicated that certain species positively correlate with certain sites and can be associated with certain habitats occurring at those

specific sites. For example, the *C. rendalli* can be associated with Site 6 (Nyamiti Pan) as this is the type of habitat they prefer in order to breed. *Hydrocynus vittatus*, although found throughout the floodplain, also prefer the pan because it has a wide variety of food sources. Very little literature is available on the breeding habits of these fish and whether they breed in this pan is uncertain at this point. *Oreochromis mossambicus* also prefer Nyamiti Pan as a refuge but the data are skewed by the fact that they are the most common species throughout the floodplain. The data showed that smaller species like the barbs and certain species of Labeos are associated with the river sites due to the flow.

The Redundancy Analysis (RDA) tri-plot distinguishes between high flow and low flow on the horizontal axis. Species that prefer low flow conditions are grouped above the first axis. These were either species that positively correlated with the pan sites (6 and 10) or the river sites during low flow (November, July and September). These species include various barb species and *O. mossambicus*, which have a tolerance for a wide range of environmental variables. The environmental variables associated with low flow also support the occurrence of the more tolerant species caught in the low flow.

The vertical axis distinguishes between river and pan sites. River sites positively correlated with higher oxygen levels due to aeration of the flow and faster flowing water facilitating fast deep and fast shallow habitats as well as more in-stream vegetation. Species that prefer these conditions were closely grouped together at the river sites. These species included *M. acutidens, T. sparrmanii* and *G. callidus*. Pan sites are associated with lower oxygen levels due to the still-standing water and lack of in-stream vegetation, and higher conductivity due to higher levels of Total Dissolved Salts (TDS) as well as higher temperatures due to the habitat types (slow shallow and slow deep). The species linked with this type of environment included *O. mossambicus, C. rendalli, C. gariepinus* and *H. vittatus*.

3.4.5 Fish biodiversity

Historic results indicated that 37 species occurred in the Phongolo Floodplain (Merron *et al.* 1993a), but the loss of five species occurred over a period of 10 years mainly due to an extreme drought of 1983. The five species that were not present after the drought included: *A. nebulosa labiata, A. marmorata, A. bicolor bicolor, L. marequensis* and *N. orthonotus.* Recent results from 2012 to 2014 indicate that 37 species were present in the Phongolo Floodplain. Species that were present in the floodplain after the severe drought (1984 survey) but were not found during

recent surveys include: *L. congoro, B. viviparus, M. brevianalis* and *C. ngamensis*. Several species were found in the recent surveys that were not recorded during the initial survey of 1974; these species include: *A. bengalensis labiata, L. marequensis, B. unitaeniatus, M. cyprinoides, O. placidus, A. aeneofuscus* and *C. carpio*. The changes in community structure and the occurrence and disappearance can possibly be linked to the variation and timing of the high flows and low flows in the floodplain.

In total, 44 fish species from 12 families have been reported from the lower Phongolo River and Floodplain. Of these species, the tigerfish, *H. vittatus* and the black tilapia, *O. placidus* were included in the South African threatened or protected species list (TOPS-list) of 2007 (NEMBA, 2007). Recently (2013) the Mozambique tilapia, *O. mossambicus*, was also included in the Protected Species category (NEMBA, 2013). To date, one exotic species, the common carp (*C. carpio*) has been reported from this region.

3.5 Conclusion

The original decision suggested by scientists in the early 1970s to simulate the natural flow of the Phongolo River through the release of artificial floods in order to maintain the ecological integrity of the floodplain was not consistently followed. Great variation in the flood regime occurred from 1986 to 2004. From 2005 it was decided that the flood regime should be standardized and for the past 10 years floods were released during spring, which differs from the natural high flow season which occurs during the summer months. This shift in high flow season had a significant effect on the fish communities of the floodplain. Several species that are dependent on high flow during the summer months in order to breed are now left with very little, if any habitat and often seek refuge in pans that eventually dry up. Drastic changes in the fish community structures have occurred as result of inconsistent flood releases and since 1984 five species were not found during this study. The Ndumo Game Reserve and the conserved pans in this reserve are of fundamental importance for the fisheries in the flood plain. Several economically important species such as *O. mossambicus, C. rendalli, L. rosae, S. zambezensis, C. gariepinus* and *H. vittatus* utilize these pans as refugia, ultimately recruiting the fish in the Phongolo River. Therefore the importance of summer floods in the Phongolo Floodplain should again be emphasized in order to maintain the ecological integrity of this system.