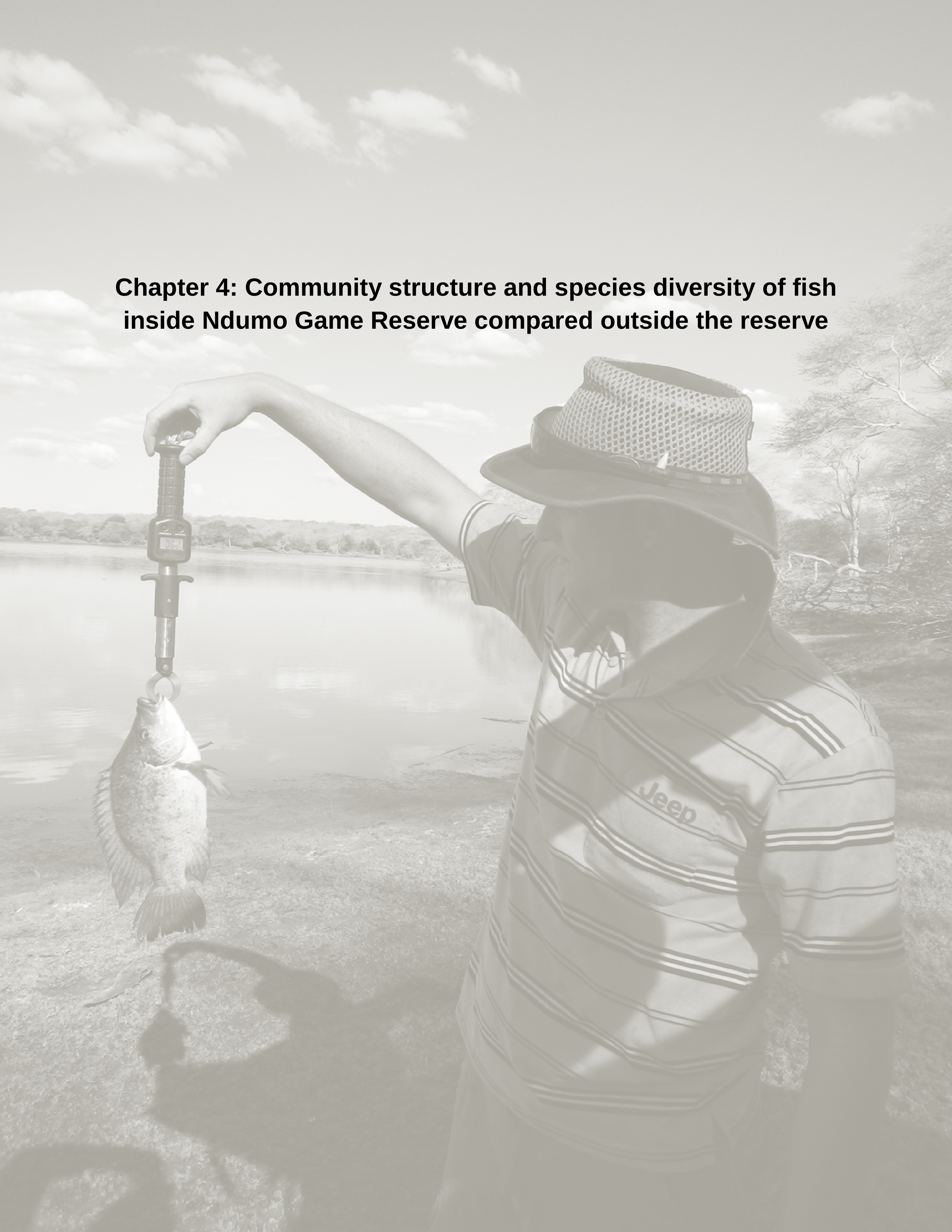
Chapter 4: Community structure and species diversity of fish inside Ndumo Game Reserve compared outside the reserve



4.1 Introduction

Over the past decades several studies have been done on the minimum hydrological requirements, habitat alteration, flow modification and the effects of drought on the fish communities living in rivers (Kushlan, 1976; Gorman & Karr, 1987; Bain *et al.,* 1988; Merron, 1994a; DeAngelis *et al.,* 2010; Naghibi & Lence, 2012). The findings of these studies all indicate that a minimum hydrological standard (minimum flow requirement) needs to be maintained in order to preserve the integrity of aquatic organisms by ensuring refugia during drought events. The problem with maintaining these standards is the complexity of understanding the interdisciplinary ecosystem.

Arthington *et al.* (1999) did a study on the establishment and monitoring of the in-stream flow requirements for the river courses downstream of the Lesotho Highlands Water Project Dams and they emphasized certain aspects of the flow regime that should be maintained in order to adequately protect specific features of ecosystem functioning. These aspects include:

Low flows: Surface flows must be maintained through the drier months with a gradual increase of base flows as the natural rainfall increases. It is important to maintain a constant flow in perennial rivers to prevent encroachment of riparian vegetation into the stream bed. If the flow is too low it will result in isolated pools that can result in the loss of biota as they could potentially dry up.

High flows: The most important aspect of high flow is to simulate the natural flow which will result in the maintenance of the active channel and channel form. This in turn will ensure the maintenance of the physical habitat conditions for various fish species. During high flow the main channel is connected to the various backwater pools and pans and must be maintained during the summer months when newly recruits are entering the system. High flow events also flush the various lentic water bodies (pans) from deteriorating water quality.

Natural flow variation: Flow variation can be regarded as a form of disturbance, yet it is an important factor in river ecology as it facilitates biological diversity by increasing the environmental heterogeneity. The loss in variability may allow the few superior competitive species to become dominant while it limits the opportunity for the rare species. This can ultimately lead to a loss in species richness.

Natural flow pattern: The natural flow pattern can be regarded as an element of flow variability and for the purpose of this study it will be taken into context as seasonal patterns. It is difficult to determine the natural flow of rivers as it can occur in almost any month. Long-term flow results and rainfall data, however, can be consulted in order to form trends (See Chapter 3). Fish in systems with unpredictable flow regimes can rapidly respond to and recover from changes caused by floods (Poff & Ward, 1989). Arthington *et al.* (1999) went on to say that this may be true for the generalist species with wide environmental tolerances that are widely distributed.

4.1.1 The role of Ndumo Game Reserve

The only part of the Phongolo River that is protected from direct human impact is a 15 kilometer reach that flows through the eastern section of the Ndumo Game Reserve. This part of the river, and its associated pans, is regarded as the reserve for the fish diversity in this system as no fishing or exploitation of any sort is allowed inside the game reserve.

Fish are good biological indicators to determining aquatic health in that they are widely distributed, easy to identify, can provide information of both long-term and short-term impacts and provide integral assessment results (Naghibi & Lence, 2012; Jia & Chen, 2013). Fish also use stream environments in a 3-dimensional way in that they specialize in specific habitats, complexity of habitats and the periodic phenomena such as low flow and water quality characteristics (Gorman & Karr, 1987). Therefore, this chapter will focus on using fish diversity in the Phongolo River by comparing two sites, one outside Ndumo Game Reserve with one inside the Reserve to determine the health status of the river at these two sites. In order to do this the ecological category of each site must be determine to directly compare the sites.

4.1.2 Ecological Category determination using the Fish Response Assessment Index (FRAI)

Eco-status can be defined as the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and its capacity to provide a variety of goods and services (Kleynhans, 2007). The Eco-status of a system can be determined through a multi-disciplinary ecological classification process. This process refers to the determination of the present ecological state of rivers relative to the natural reference condition of that river (Kleynhans, 2007). The eco-classification process is made up by a suite of models which include:

- Hydrological Driver Assessment Index (HAI)
- Geomorpholgical Driver Assessment Index (GAI)
- Physico-chemical Driver Assessment Index (PAI)
- Fish Response Assessment Index (FRAI)
- Macro Invertebrate Response Assessment Index (MIRAI)
- Riparian Vegetation Response Assessment Index (VEGRAI).

The first three indices (HAI, GAI and PAI) are the driver indices and the information required from these drivers refers to the information contained in individual metrics. This information can then be used to interpret the habitat required by the biota (FRAI, MIRAI and VEGRAI), which in turn can be used to determine and interpret biological responses. For the purpose of this chapter, only the FRAI model will be used to determine Ecological Category (EC) scores (Table 4.1) for the fish of the Phongolo River at two sites, one inside and one outside the Ndumo Game Reserve.

In order to relate the ecological drivers to the stress responses of fish, detailed information on the life history requirements and environmental preferences of species is provided in the FRAI model (Kleynhans, 2007). Thus the life history, habitat requirements and preferences of each of species in the fish assemblage are taken into account. If the database was for some reason not sufficient, literature and experts were consulted as prescribed by Kleynhans (2007). Habitat features are assessed according to their suitability to the requirements of the species forming the assemblage. These requirements include: breeding, early life stages, frequency of occurrence, cover, abundance, health and water conditions.

Based on the information above, the sites are assigned a numerical score and are classified into the different categories described in Table 4.1.

Table 4.1: The Ecological Category (EC) description of rivers (adapted from Kleynhans, 2007).

Ecological Category	Description	FRAI Score (%)
A	Unmodified	90–100
B	Largely natural with few modifications. A small change in natural habitat and biota may have taken place but the ecosystem functions are essentially unchanged.	80–89
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	60–79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40–59
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	20–39
F	Critically/Extensively modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and changes are irreversible.	0–19

4.2 Materials and methods

At each site the available fish habitat was classified based on the velocity and depth parameters described by Kleynhans (2007) and in each habitat type, or velocity-depth class, the extent of the potential cover for the fish, namely substrate, overhanging vegetation and undercut banks, was estimated and scored. During each survey the existing conditions, which included turbidity, water colour and flow were observed and recorded. Fish were sampled at the sites according to the habitat specific protocol described by Kleynhans (2007) and the collected fish specimens were identified on site using the key provided by Skelton (2001). The data was used to calculate Fish Response Assessment Index (FRAI) scores (Kleynhans, 2007). This index is based on the environmental intolerances and preferences of fish and their resultant response to changes in environmental drivers (Kleynhans, 2007). The Reference State (RS) for each site was calculated based the Frequency of Occurrence (FROC) data provided by Kleynhans (2007).

For the calculation the River Ecoclassification: Manual for Ecostatus Determination, Module D: Volume 1 Fish Response Assessment Index (FRAI), was used (Chapter 2).

4.3 Results

4.3.1 Species diversity

It is important to note that the high flow and low flow data were pooled respectively, for the calculation of the Ecological Category (EC) of the two sites on the Phongolo River. The EC scores for the low flow and high flow were calculated separately to determine if there is a significant difference between the flow conditions. The first site was Site 2, situated downstream of the Pongolapoort Dam, outside of the Ndumo Game Reserve (see Chapter 2). The second site was Site 7, situated inside Ndumo Game Reserve (Chapter 2). These two sites were compared in order to determine the effect of Ndumo Game Reserve on the biodiversity and more specifically the Frequency of Occurrence (FROC) of certain fish species in the Phongolo River.

Table 4.2: Species diversity and number of individuals caught at two sites on the Phongolo River during low flow and high flow.

		Low flow		**High flow**	
Species	**Abbrev.**	**Site 2**	**Site 7**	**Site 2**	**Site 7**
Alestidae					
Brycinus imberi (lateralis)	BIMB	X	X		X
Hydrocynus vittatus	HVIT			X	
Micralestes acutidens	MACU	X	X	X	
Anguiliidae					
Anguilla bengalensis labiata (nebulosa)	ALAB				X
Anguilla marmorata	AMAR	X		X	
Anguilla mossambica	AMOS				
Cichlidae					
Coptodon rendalli (Tilapia rendalli)	TREN			X	
Oreochromis mossambicus	OMOS	X	X		X
Tilapia sparrmanii	TSPA	X		X	
Clariidae					
Clarias gariepinus	CGAR		X	X	X
Cyprinidae					
Barbus afrohamiltoni	BAFR		X		X
Barbus pallidus	BPAL		X		
Barbus paludinosus	BPAU		X		X
Barbus toppini	BTOP		X		

		Low flow		High flow	
Species	**Abbrev.**	**Site 2**	**Site 7**	**Site 2**	**Site 7**
Barbus trimaculatus	BTRI	X	X	X	
Barbus unitaeniatus	BUNI	X	X		X
Labeo cylindricus	LCYL	X	X	X	
Labeo molybdinus	LMOL		X		
Labeo rosae	LROS		X		
Gobiidae					
Glossogobius callidus	GCAL	X	X		
Glossogobius giuris	GGIU	X	X	X	
Megalopidae					
Megalops cyprinoides	MCYP				X
Mochokidae					
Chiloglanis paratus	CPAR	X			
Synodontis zambezensis	SZAM		X	X	X
Mormyridae					
Marcusenius macrolepidotus	MMAC		X		X
Petrocephalus wesselsi (catostoma)	PCAT		X		X
Schilbeidae					
Schilbe intermedius	SINT		X		X
Total no. of species		11	19	10	12

The River Health Programme (RHP) reference site used for this part of the study was W4PONG-KOSIB (Kleynhans, 2007).

4.3.1.1 Comparison of species diversity of Site 2 and Site 7 during low flow and high flow.

During low flow a total of 11 species were collected at Site 2 and the dominant species was *M. acutidens* compared to a total of 19 species collected at Site 7, which was dominated by *M. macrolepidotus* and *B. paludinosus* (Table 4.2). Conversely, during high flow 10 species were found at Site 2, still dominated by *M. acutidens* and also *T. sparrmanii,* and only 12 were found at Site 7 compared to 19 that were found at the same site during low flow. The dominant species at this site was *P. wesselsi* (Table 4.2).

4.3.1.2 Comparison of species diversity at Site 2 during low flow and high flow.

Over the series of five surveys, a total of 15 species of the expected 30 species (Kleynhans, 2007) were collected at Site 2. During low flow five species were present which were not collected during the high flow, and during high flow four species were present that were not sampled during the low flow (Table 4.2).

4.3.1.3 Comparison of species diversity at Site 7 during low flow and high flow.

Over the series of five surveys, a total of 20 species of the expected 30 species (Kleynhans, 2007) were collected at Site 7. During low flow 8 species were present that were not sampled during high flow and during high flow only two species were present that were not sampled during low flow (Table 4.2)

4.3.1.4 Comparison of the overall species diversity at Site 2 and Site 7.

At Site 2, six species were found that were not present at Site 7, and at Site 7 a total of 10 species were found that were not present at Site 2 (Table 4.2)

4.3.2 Fish Response Assessment Index (FRAI)

During the low flow season the EC score of Site 2 was 61.4 compared to the 69.9 of Site 7 (Table 4.3). Both sites during the low flow were classified as moderately modified. During high flow, however, the scores of both sites decreased to 54.1 for Site 2 and 55.1 for Site 7, and were both classified as largely modified.

Table 4.3: Fish Response Assessment Index (FRAI) scores for the selected sites in the Phongolo River during low flow and high flow.

Low flow		High flow	
Site 2 (outside)	**Site 7 (inside)**	**Site 2 (outside)**	**Site 7 (inside)**
61.4	69.9	54.1	55.1
C/D	C	D	D

4.4 Discussion

4.4.1 Site 2 (Outside the Game Reserve)

It is evident from the results that during low flow species that prefer riffles and slow-flowing water are present and more abundant compared to high flow. This might be attributed to the fact that a riffle section of the river is exposed during low flow, which creates a suitable habitat for species like *C. paratus.* Other species such as *O. mossambicus* that prefer slow-flowing water and pools were also only present during low flow in vegetated pools. High flow facilitated a change in the species composition of Site 2. Although fewer species were found during high flow, the species that were found were all species that prefer flowing water, with the exception of *C. rendalli*; these species include *H. vittatus* and *L. cylindricus.* The reason for the presence of *C. gariepinus* and *L. cylindricus* during the high flow is that they are flood respondent spawners (Bruton, 1979). This means that after heavy rains, when the water level rises, these species spawn in marginally inundated areas, laying eggs on the vegetation (Bruton, 1979, Skelton, 2001). The presence of *H. vittatus* during high flow can be attributed to a number of factors. Firstly, this species prefers well oxygenated water (Skelton, 2001), which is a result of the flood release from the impoundment upstream and its and the proximity to Site 2. Secondly, this species migrates upstream during the summer months (Steyn *et al.,* 1996; Van Loggerenberg, 1983), mainly to breed (Badenhuizen, 1967; Skelton 2001). Another reason for the absence of various species during high flow could be the presence of the two above-mentioned species, as they are the dominant predators in this system.

4.4.2 Site 7 (Inside the Game Reserve)

During low flow the fish diversity was higher at Site 7 compared to high flow. This might be due to the fact that this site is dominated by slow-flowing pools with overhanging vegetation. This possibly facilitated the presence of certain species of barbs and Labeos. During high flow none of these species were present. The reason the barbs were not present can be attributed to a number of factors. One might be because they migrated upstream to spawn, although it is unlikely, because these are not migratory species. A second possible reason for the absence of these species is the fact that during high flow the river is connected to the surrounding pans. This might enable barbs to enter the pans, as these are more stable and suitable habitats for them to breed and take refuge from strong flows (DeAngelis *et al.*, 2010). The absence of the various Labeos during high flow may be attributed to them migrating upstream to spawn

(Skelton, 2001). One of the main reasons for the high fish diversity during low flow may be the flow regime. During low flow the fish are forced into the river because of the receding water line. During high flow, however, the fish are free to move into the surrounding pans, which cause a lower diversity in the river.

4.4.3 Fish diversity of the Phongolo River

The overall combined diversity of Site 2 indicated that a total of 15 species were present at this site. Six of these species were not present at Site 7. The reason these species were only found at Site 2 may be that riffles are exposed during low flow, creating a suitable habitat for most of these species as well as in-stream vegetation, while at Site 7 there are no riffles during high or low flow. Thus, the absence of these species from Site 7 may be attributed to the lack of suitable habitat. Conversely, the overall combined diversity was higher at Site 7, with a total of 20 species collected. Eleven of these species were not recorded at Site 2. The Mormyridae are a nocturnal species (Skelton, 2001; Engelbrecht *et al.,* 2007) and were only ever caught at night (Chapter 2). This might explain why these species were not found at Site 2. *Barbus afrohamiltoni* and *B. paludinosus* were present at Site 7, and were not found at Site 2. This might be attributed to the close proximity of various pans along the stretch of river inside the Game Reserve. These species were abundant in the surrounding pans close to Site 7 (See Chapter 3 on community structures). DeAngelis *et al.* (2010) did a study on fish population dynamics in a seasonally varying wetland and saw a similar trend where fish in the Everglades moved to smaller water bodies such as sink holes and alligator ponds as the water level were receding. This phenomenon was termed ‘refuge mechanism’. Two species of Labeo were recorded at Site 7 that were not present at Site 2. This can possibly be attributed to habitat suitability, as both *L. molybdinus* and *L. rosae* prefer deeper water. The presence *A. bengalensis labiata* can also be because of its migration up the Phongolo River, as all Anguillidae are migrating species. It is well documented that they move on catchment scale (Skelton 2001; Kleynhans, 2007).

4.4.4 Fish Response Assessment Index

The EC score indicates the Phongolo River falls within the moderately modified class during low flow. Site 2 is bordering on the largely modified class, but Site 7 is in the best condition during low flow. What was interesting to note was the notable decline of the EC scores at both sites during high flow. Because of the increased flow a number of species were not present in the river during high flow surveys and this had a profound effect on the EC scores. The reason many of these species were not present during high flow was either due to habitat loss or the ‘refuge mechanism’ as discussed earlier. If the latter is the reason for the absence of certain species, it means that they move to the surrounding pans to seek refuge and/or to breed and repopulate the river.

Another reason for the low EC score of the Phongolo River might be because a number of the reference species from the Phongolo River were not found. After extensive sampling from 2012 to 2014, a total of four of these reference species were not found; these include: *C. ngamensis, M. brevianalis, L. marequensis* and *L. congoro*.

Clarias ngamensis prefers well vegetated habitats and spawns in shallow channels during summer (Skelton, 2001). The absence of this fish might be due to the lack of slow channels during summer months, as this is when the floods are released. Merron *et al.* (1993b, 1994a–e) did record this species in various pans along the Phongolo Floodplain. More sampling is required to determine whether this species still occurs in the Phongolo River and to better understand its biology and ecology in this river.

Mesobola brevianalis is also listed as a reference species and was recorded on several occasions in the Phongolo River during the early 1990s by Merron *et al.* (1993b, 1994a–e). This species prefers open flowing, deep water and breeds in early summer (Skelton, 2001). Possible reasons for the absence of this species might be habitat loss during the early summer months due to the irregular flood regime or that it falls prey to various predators like *H. vittatus* or *C. gariepinus* sharing the same habitat. Extensive targeted sampling is required to establish whether there are still *M. brevianalis* populations in the Phongolo River.

Although *L. marequensis* were not sampled during this survey nor any of the surveys done by Merron *et al.* (1993b, 1994a–e), the species was still present before the major drought of 1983 (Merron *et al.*, 1994a). One of the possible reasons for the absence of this species might be that the population was severely affected by Cyclone Domoina, which hit the area during the rainy season (February) of 1984. Because this species breeds in spring and early summer (Skelton, 2001), the juveniles could have easily been washed downstream. This species does not occur in dams or lakes and will unlikely seek refuge in these areas due to the absence of their food source.

Labeo congoro were recorded in the Phongolo River by Merron *et al*. (1993b, 1994a–e), but were not found during this survey. One of the possible reasons for the absence of this species might be habitat loss due to irregular flooding events, as this species occurs in strong-flowing, rocky reaches of rivers (Skelton, 2001).

The high numbers and diversity of species found in various pans along the lower stretch of the Phongolo River (Chapter 3) confirms that certain species use the pans to breed during summer months. This, in turn, again emphasizes the importance of the pans inside the Ndumo Game Reserve. The bodies of water in this reserve serve as important refugia for fish species because there is no direct human impact such as fishing. Because of the exploitation of fish along the floodplain as protein source for the indigenous people, the fish that take refuge in the pans that are located outside the Game Reserve will most probably be caught. The fry of the species that will be able to spawn will either be trapped by the receding water levels as the dry season approaches, or will also be caught by the indigenous people. The locals will often use shade cloth as makeshift seine nets and there are no limits on size or how many fish an individual belonging to the community can take home (pers. com.). This has a major effect on the fish communities and fish population of the Phongolo River outside the Game Reserve. If the recruits are caught before getting a chance to reach sexual maturity and breed, the fisheries of the river will decline rapidly.

Naghibi & Lence (2012) conducted a case study on the Lower Campbell River (Canada), assessing the impacts of high flow events on fish populations. In their study they concluded that immediate egg loss had a higher impact on the estimated risk based performance than immediate fish loss. The reasons for this phenomenon are that the rate of egg loss is much higher than the rate of fish loss due to the fact that fish lay thousands of eggs at a time. Secondly, adults can survive major floods and can still spawn after the flood has occurred, but all the eggs that are deposited before the flood are subject to the impacts related to that flood. If this is the case in the Lower Phongolo River it might explain the absence of species like *M. brevianalis* and *L. congoro* (Chapter 3). Although egg loss has a higher impact on population structure and recruitment, the fish loss is just as important and should not be neglected.

Irregular floods and the associated high flow could facilitate the colonizing of various species that have greater environmental tolerances. If these irregular floods that do not simulate the natural flow conditions continue, it could cause the disappearance of the more sensitive species in the future (Arthington *et al.,* 1999).

4.5 Conclusion

The fish diversity inside Ndumo Game Reserve (Site 7) was far greater than the diversity outside the Game Reserve (Site 2), emphasizing the importance of Ndumo Game Reserve as a refuge and for the conservation of the Phongolo River's fish diversity. Results from this chapter indicate that during low flow certain fish flourish in the river at Site 7; however, during the high flow these species seek refuge in the surrounding pans. This was also the case with the fish from outside the Game reserve, although when they seek refuge in the pans outside the Game Reserve they are often caught by the local communities.

It is clear that the different flows have an effect of the fish communities in the Phongolo River, benefiting certain species and negatively influencing others. The role of the pans in Ndumo Game Reserve should be emphasized as they play an important role in the recruitment process of various species that will ultimately repopulate the river. This in turn raises concern with regard to the flood regime and its timing. The flow of the Phongolo River must be regulated to simulate the natural flow because the majority of the native fish in this river are not only summer spawning species but are also flood dependant spawners. If the flood regime does not simulate the natural flow of the river it could lead to the loss of fish diversity in the long term.

The fish diversity and the effect of the flood releases on this diversity can be used as a guideline along, with the natural flow of the river in order to conserve and protect the aquatic biodiversity of the Phongolo River (Chapter 6).