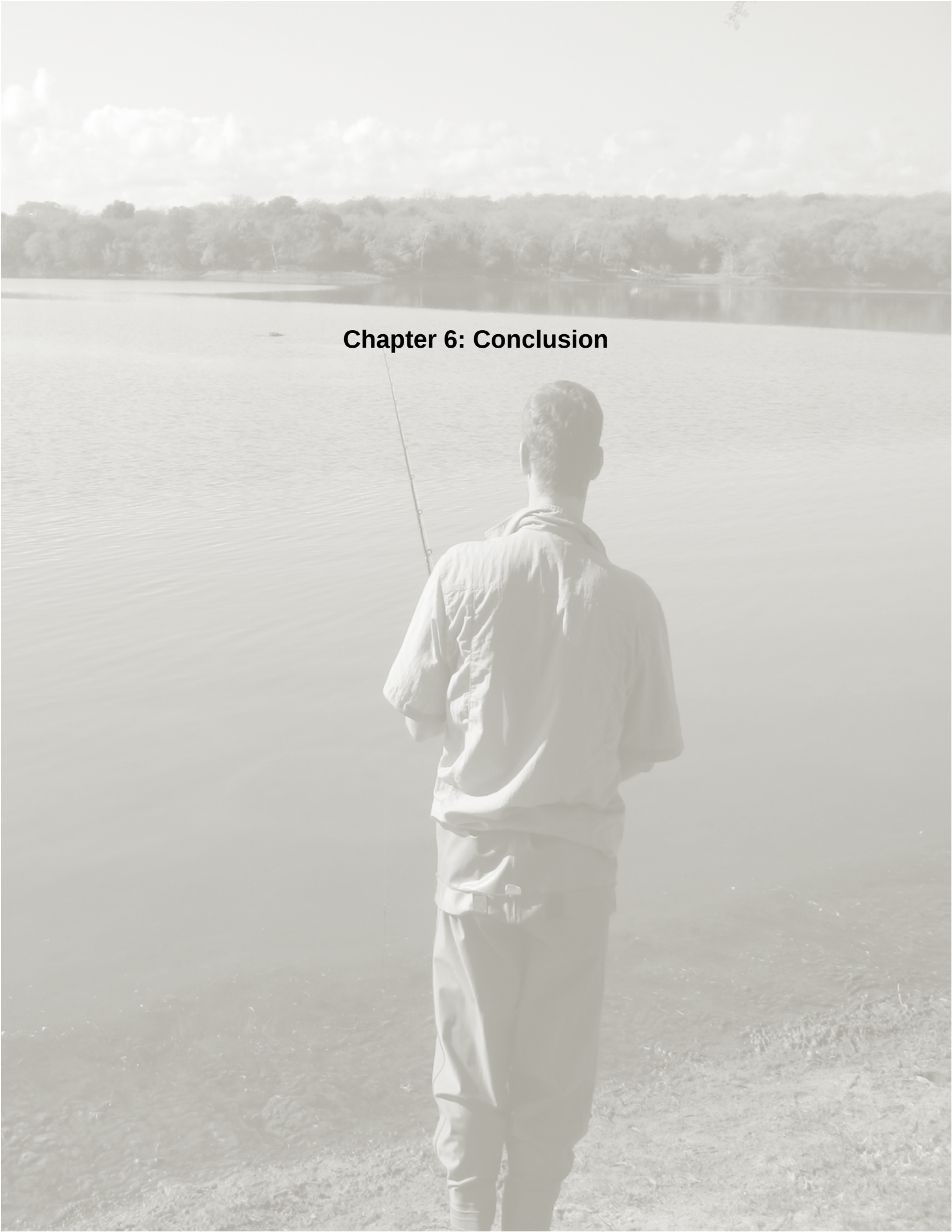


A grayscale photograph of a person fishing by a lake. The person is seen from behind, standing on a grassy bank and holding a fishing rod. The lake is calm, reflecting the sky and the distant forest. The text "Chapter 6: Conclusion" is overlaid on the image.

Chapter 6: Conclusion

6.1 Introduction

This study formed part of a larger Water Research Commission (WRC Project K5-2185) project entitled: 'Ecosystem functioning, sustainable utilization and management of aquatic resources of the lower Phongolo River and Floodplain'. Within this larger project the focus of this study was to address the questions related to the ecosystem functioning of the Phongolo River and Floodplain, specifically in relation to the flooding events due to releases from the Pongolapoort Dam. Several studies over the past decades have emphasized the importance of maintaining the natural flow regime of a river (Bain *et al.*, 1988; Gorman & Karr, 1987; Williams *et al.*, 1989; Merron *et al.*, 1993a; Arthington *et al.*, 1999; Olden, 2002; Moerke & Lamberti, 2003; Naghibi & Lence, 2012; Cote *et al.*, 2013). All these studies determined that floods, or the lack thereof, have a major effect on fish communities. Arthington *et al.* (1999) described aspects of the flow regime that must be maintained in order to adequately protect certain features of an ecosystem and its functioning. Environmental flow conditions are of fundamental importance for riverine species assemblages. These flows, whether high or low, sustain fish populations through the maintenance of the floodplain morphology, hydraulic habitat conditions, water quality conditions, food resources, opportunities for migration and other organisms in the river and riparian environment (Arthington *et al.*, 1999). In the light of this, three aims were set for this project. This chapter will revisit those original aims and discuss how the results of the study addressed them.

6.2 Aim 1: The effect of irregular flood releases on the fish community structure in the Phongolo River and floodplain

Following the completion of the Pongolapoort Dam in 1974, the flow regime in the Phongolo floodplain was greatly altered (Merron *et al.*, 1993a). This led to a study to establish a fisheries management programme for the fish communities in the Phongolo Floodplain (Merron *et al.*, 1993b, 1994a–e). The original decision suggested by scientists, to simulate the natural flow regime of the Phongolo River through the release of artificial floods to maintain the ecological integrity of the floodplain, was not followed. The first aim of the present study was therefore 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. To achieve this, the sites used in the 1993 and 1994 surveys by Merron *et al.* (1993b; 1994a–e) were resampled to compare with recent data. The results of the present study showed that the irregular flood releases from 1984 to 2005, together with the unnatural flows during

spring (September to November) from 2005 to 2013, have changed the fish community structure of the Phongolo floodplain and might be the cause for the absence of certain species – such as *Labeo congoro*, *Barbus viviparus*, *Mesobola brevianalis* and *Clarias ngamensis* (Chapter 3). Historic data revealed that although the flood releases from 2005 to 2013 were consistent, they were released during the wrong season. Records show that 60% of the natural flow occurs in summer (December to February), which coincides with the high rainfall period. However, it was observed that 64% of the flood releases were done in spring (September to November) and only 16% during summer months.

Several species, including *L. rosae*, *S. zambezensis*, *C. gariepinus* and *H. vittatus*, are dependent on summer floods as this is one of the cues for them to breed. One of the main reasons why these species breed when water levels are high is because the increase in water level means that the riparian vegetation is inundated and provides suitable breeding habitat. The vegetation also provides cover for the juvenile fish. Another reason, with specific reference to *H. vittatus*, is the need to migrate upstream for breeding, and obstacles cannot be navigated during low flows. Results of the present study showed that economic and social important species, such as *O. mossambicus* and *C. rendalli*, seek refuge in the pans along the floodplain and use these habitats to breed (Chapter 5). Irregular or unnatural floods affect several species that are dependent on high flow during the summer months in order to breed when the water level of the floodplain are low. These species are left with very little, if any, habitat in the river and often seek refuge in pans that eventually dry up, or are caught by the locals. Alterations in the flood regime change the available habitats along the river, ultimately affecting the fish in the river. The present study also showed that there is great variability among fish species diversity and their frequency of occurrence between high and low flow (Chapter 4).

The absence of species such as *Mesobola brevianalis* and *Labeo congoro* raised concerns, as these species might have been negatively influenced by the irregular and unnatural flows of the past decades. The flows could have led to a loss of suitable habitat. In order to determine whether these species have disappeared from this area, targeted sampling for this species must be carried out in the future. The presence of certain species such as *A. bengalensis labiata*, *A. aeneofuscus* and *O. placidus* was noted during the recent surveys (2012–2014) and they were not present in historic surveys (Merron *et al.*, 1993a–b, 1994a–e). The presence of *A. bengalensis labiata* during the present study can be attributed to the migratory characteristics of this species. *Awaous aeneofuscus* was found in the Usutu River but was not sampled during the

historic surveys, even though it does occur in this system. The natural distribution of *O. placidus* is along the east-coastal rivers of southern Africa (Skelton, 2001). It is possible that this species entered the Phongolo River via the Maputu River in Mozambique. This species has previously been recorded in the Mkuze swamps in St. Lucia (Skelton *et al.*, 1989).

This study therefore shows that one result of the irregular floods of the past decades is a change in fish community structure that has led to the potential disappearance of flow-sensitive species and the increase in dominance of other generalists. These shifts in species dominance may have a detrimental effect on overall species biodiversity and need to be investigated further.

6.3 Aim 2: Diversity and abundance of fish inside and outside the Ndumo Game Reserve

The second aim of this study was to compare the diversity and abundance of fish inside the Ndumo Game Reserve with sites outside the reserve. To achieve this aim, similar sites inside and outside the Ndumo Game Reserve were selected and sampled for fish diversity and community structures. The community structure and abundance of the selected sites were compared using applicable statistical analysis (the results of this aim are discussed in Chapter 4 of this study). Based on the results obtained it was concluded that the Ndumo Game Reserve plays an important role in the diversity of the fish in the Phongolo Floodplain and its associated rivers. Results indicated that the fish diversity is higher within Ndumo Game Reserve than in sites outside the reserve (Chapter 4). The results also indicated that the fish diversity in the river is lower during high flow compared to low flow. This is attributed to the fact that during high flows the surrounding pans are inundated and this creates suitable habitats which serve as refuge areas for species to breed. During high flow events, the fish move from the river into the pans in order to breed, which indicates the importance of the pans and their associated habitat for the recruitment of fish into the river. This raises a concern with regard to the flood regime and its timing and the effect it has on the fish communities and populations in the floodplain.

One of the most important pans in the Ndumo Game Reserve, Nyamiti Pan, is a permanent water body and is connected to the Phongolo River during high flows. A number of economically important species such as *O. mossambicus*, *C. rendalli*, *L. rosae*, *S. zambezensis*, *C. gariepinus* and *H. vittatus* utilize these pans as refugia, ultimately replenishing the fish diversity and abundance in the Phongolo River. It is evident that all the species from Nyamiti Pan,

especially the cichlids, are dependent on the floods and their associated high water level. Historic data indicate that the drought of one year (2008) had a detrimental effect on the population structure of *O. mossambicus* and *C. rendalli* in Nyamiti Pan (Chapter 5).

6.4 Aim 3: Determining the health status and population structures of selected fish species within Ndumo Game Reserve

The third aim was to determine the population structure and health of selected fish species within Ndumo Game Reserve and to compare it to those in areas outside the game reserve. The health status of *O. mossambicus*, *C. rendalli*, and *H. vittatus* from Nyamiti Pan was determined using both micro- and macroscopic health assessment methods. The population structure of these species was investigated with age determination, using otoliths. The results, discussed in Chapter 5, showed that the health of *O. mossambicus* in Nyamiti Pan is under pressure due to high internal and external parasite infestation by nematodes and *Lernaea cyprinacaea*, respectively. The alien parasite *L. cyprinacaea*, is a natural parasite of the alien fish species, *Cyprinus carpio*, that was present in various pans in Ndumo Game Reserve. The condition factor of *O. mossambicus* was significantly lower than *C. rendalli* and was directly affected by flood regime. The above-mentioned parasites also seem to prefer *O. mossambicus* as host and this species was severely infected by both these parasites. Population structure composition indicates that Nyamiti Pan was mainly populated by adult cichlids ranging between six and ten years old. The presence of large numbers of larvae of both these species confirmed that they breed in Nyamiti Pan (pers. obs.). Very few juvenile cichlids were found in the pan, but juveniles were found at the outflow in the shallow water adjacent to the river, suggesting that they migrate into the river after they reach a certain age.

The concerns raised by these findings are that the *O. mossambicus* population in Nyamiti Pan is under pressure due to multiple stressors. The health of this species is at risk due to the high parasite infestations. Further research on the effect of these parasites on the health of *O. mossambicus* is needed. It is documented that salinity levels in Nyamiti Pan fluctuate over different seasons (Heeg & Breen 1982) and that regular flooding plays an important role in the flushing of this system. It is not known, however, what role this fluctuation and flushing plays in the health of the fish in the pan.

Based on the high number of juvenile *C. carpio* found in various pans in Ndumo Game Reserve, it is possible that these species also breed in these pans. The concern regarding these species

is that they are an alien invasive species in South Africa and are responsible for the presence of the invasive parasite *L. cyprinacaea*, which seems to attack the economically important *O. mossambicus*. A second cause for concern regarding this species is that they compete for the same resources as *O. mossambicus* and *C. rendalli* (Skelton, 2001). The pans, especially those inside Ndumo Game Reserve, seem to indicate that the refuge area (Ndumo Game Reserve) for the economically important fish is also utilized by this alien invasive species (Chapter 3). Historic data show that *C. carpio* was introduced into this system between 1984 and 1994. There is no record of this species before 1984 and it was recorded for the first time in 1994 (Merron *et al.*, 1993b). Although Merron *et al.* (1993b) did not record large numbers of this species, it did occur in more sites when compared to the present study. This might also highlight the fact that these species utilize Nyamiti Pan as a refuge, as they were not recorded at the same sites where Merron *et al.* (1993b, 1994a–e) found them.

6.5 Recommendations with regards to the flow and flooding regime

6.5.1 Low flow

Perennial rivers such as the Phongolo River must maintain surface flow throughout the year, especially throughout the drier months of the year to maintain the longitudinal connectivity of the river. A gradual increase in base flow should occur from the months with the lowest to months with the highest rainfall (Arthington *et al.*, 1999). This maintains the perennial nature and ecosystem of the river. When the flow of a river is too low, it isolates pools and they become vulnerable to deteriorating water quality and run the risk of drying up completely. When fish get trapped in these pools they either get caught by predators or harvested by the local communities. In most cases, these fish succumb in the dried out pans (pers. obs.). Sufficient flow must be emphasized because it refreshes pools by removing the nutrient build-up, increases the dissolved oxygen levels and facilitates fish movement (Arthington *et al.*, 1999). An unstable flow regime, or too low flow, can result in the loss of fish eggs and habitat loss. A gradual increase in the water level facilitates breeding in submerged vegetation and allows access to the food resources therein (Arthington *et al.*, 1999). This is important because the flow of a river is the driver of ecosystem processes such as evolutionary processes like species behavioural morphological and life history adaptations to flooding events or drought as well as the nutrient cycle (James & King, 2010)

6.5.2 High flow

High flow events that occur naturally on an annual basis must be maintained at their natural magnitude and in time with the natural flow of the river. In the Phongolo River and the surrounding area, natural rainfall increases during December to March, the summer months in the southern hemisphere. The increased flow maintains the necessary habitats required by various summer breeding fish species. An increase in flow during the high flow season will keep riffle sections and rock free from silt and sand build-ups that can change this important habitat. Increased water levels caused by high flows inundate backwater pools and can cause phytoplankton blooms and an increase in macroinvertebrates, providing additional food for juvenile fish (Arthington *et al.*, 1999). The physical connectivity of the flood plain during the summer months is of fundamental importance. Various species breed during summer and use the inundated pans as breeding sites. Once these juveniles reach a certain age they move back into the river. The protected reach of the Phongolo River inside Ndumo Game Reserve and its associated pans is important as this area is utilized by the economically important species as refugia. With regard to pans, Nyamiti Pan, particularly, with its long hydro period, is potentially the most important. High flow events also flush the deteriorating water quality build-up created during low flow. It is of fundamental importance that the flood regime simulates the natural flow of the river to stimulate the spawning of the fish communities of the Phongolo Floodplain.