Annexure 3

Fish Assessment

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FISH COMPONENT OF THE BAVIAANSKLOOF MEGA RESERVE STUDY

For

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November 2008

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1 INTRODUCTION

The purpose of the national biomonitoring programme of South Africa, the National River Health Programme (RHP), is to establish the integrity or health of aquatic ecosystems. This RHP makes use of various biological indices (Roux, 1997) which are primarily concerned with the current ecological state of selected communities of river ecosystems. These indices include the invertebrate (South African Scoring System or Macro-invertebrate Response Assessment Index), riparian vegetation (Riparian Vegetation Index or the Riparian Vegetation Response Assessment Index) and fish (Fish Assemblages Integrity Index or the Fish Response Assessment Index) indices. Fish are very useful indicators of ecosystem health in that they reflect the long term health of the system (fish are relatively long lived), they are indicators of the state of various reaches of systems (fish are mobile) and have the ability to avoid impacted areas, and are known to be sensitive to and respond differently to different stressors. Finally, fish have a high social, ecological and economic value and are well known by local formal and informal communities which make the use of fish in the assessment of ecological states of systems relevant (www.csir.co.za/rhp/). The use of the attributes of fishes in the assessment of the environmental condition of ecosystems is widely incorporated in the management of freshwater ecosystems (Kleynhans, 1999; Kotze, 2002; Karr, 1981; Karr *et al.,* 1986; Fausch *et al.,* 1990; and Belpaire, *et al.* 2000). Within the framework of the RHP an index used to assess the biological attributes of fish communities within South Africa, the Fish Assessment Integrity Index (FAII), was developed by Kleynhans 1999). This initial use of the attributes of fishes to assess the ecological state of river ecosystems primarily, within the RHP had many benefits. According to Kleynhans (1999) these benefits included:

- The index was able to reflect the response of the fish communities to human-induced environmental impacts.
- It is usable within the limits of the available information, labour, expertise and financial resources of RHP practitioners/specialists in South Africa.
- It is structured in a fashion that allows for easy adaptation (i.e. recalculation of historic index values) when information on fish assemblages improves.
- It provides information and answers within the context and framework of the recent (1998) legislation on South African water resources.
- The index is flexible enough to be useful in all the ecoregions of South Africa.
- The index has been developed within a hierarchical framework.

Following the development and use of the FAII, the Sensitivity-Weighted Fish Index of Biotic Integrity (SIBI) (Kotze, 2002) and finally the Fish Response Assessment Index (FRAI) were developed (Kleynhans, 2005). Within the RHP the FRAI is now considered to be the fish community attributes index of choice and is broadly used within South Africa today (Kleynhans, 2005).

2 AIM OF THE STUDY

The aim of this of the study is to assess the ecological state/health of six river ecosystems in the Baviaanskloof Mega Reserve by using amongst others the attributes and the community structure of fishes in these rivers. In addition, the findings of the fish attributes assessment will be used to suggest the ecological importance and sensitivity, required flows (timing and duration) to maintain the current ecological state of the fish community in the system and to suggest the implications of estimated flows (modelled) to the current fish community state. In order to reach this aim the methodologies from the EcoClassification approach will be implemented to assess the community structure of fish. The Fish Response Assessment Index or FRAI model (Kleynhans, 2005) will be implemented in an assessment of the impact of flow alterations which will be carried out by assessing the potential consequences of these alterations to the known biology of the fish communities that are considered to occur within the study area.

3 MATERIALS AND METHODS

In this study, fish assessments were carried out at eleven sites, two sites on the Baviaanskloof River, three on the Kouga River, two on Wit River (only one had water) and one site on each of the Groot, Gamtoos and Geelhoutbos rivers, from the 20th to the 24th of October 2008. In this assessment the Fish Response Assessment Index (FRAI) (Kleynhans, 2005) was used to assess the present ecological state (PES) of the fish component of the rivers assessed in the Baviaanskloof Mega Reserve. This multi-metric approach for assessing the attributes of fish communities incorporates information from individual, population and community levels into a single, ecologically-based index, reflecting the overall condition of the aquatic ecosystem.

3.1 Site selection

Sites selected for this study were primarily based on sites used in historical studies, situated within the Gamtoos River Catchment (Figure 1). These studies include historical river health programme assessments that were carried out by DWAF/Eastern Cape Parks River Health Programme. In an attempt to improve on the confidence of this assessment four new sampling sites were included in this assessment. These sites as well as the location of the "old" or historical sites are graphically represented in Figure 2.

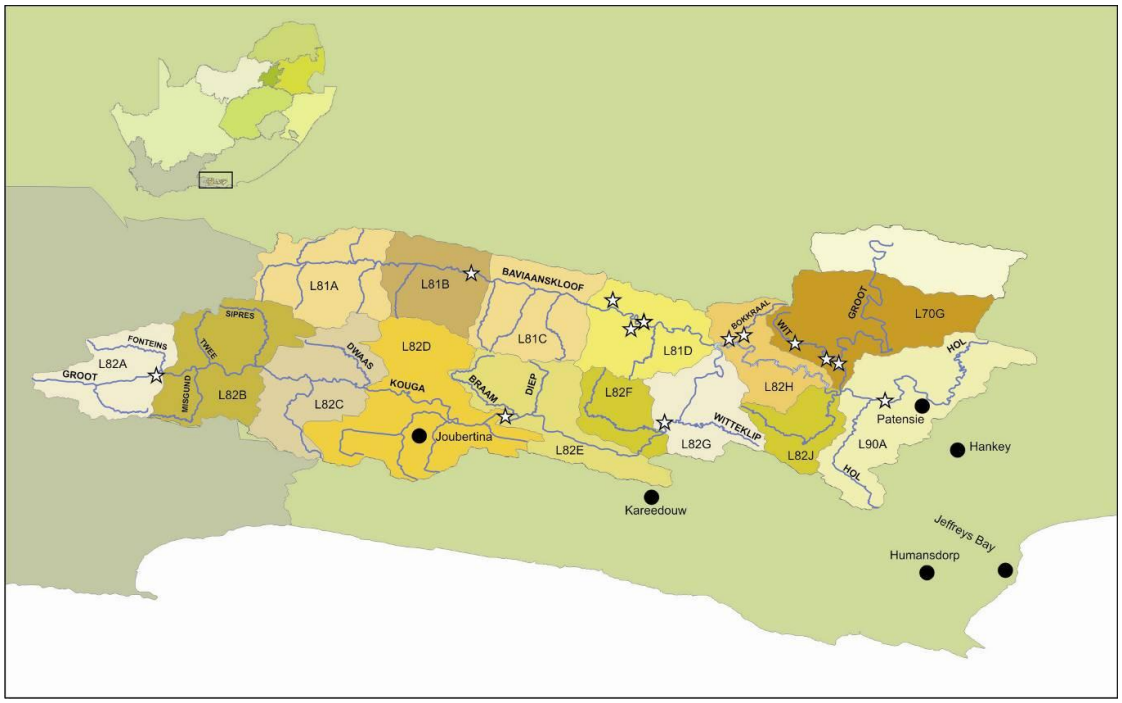

Figure 1: Location of fish assessment sampling sites for the study area

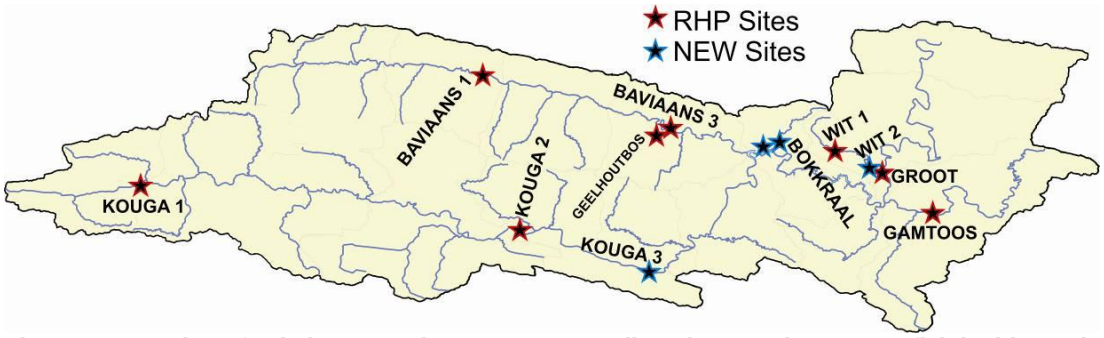

Figure 2: Location of existing RHP sites vs. new sampling sites used to assess fish in this study

3.2 Data collection

The diversity and abundance information of fishes used in this survey were collected using a range of sampling techniques including:

- Netting techniques: Gill nets (50mm mesh size) and fyke nets (2 x 10m wings with one trap) where used to sample deep pools and deep area of large rivers.
- Electrofishing: A standard SAMUS battery pack was used in the shallow wade able areas.
- Snorkelling: Where clarity conditions allowed visual observations where carried out by snorkelling in clear pools.

The fish diversity and abundance data were recorded in the field and voucher specimens where collected to later be sent to the South African Institute for Aquatic Biodiversity.

3.3 Reference conditions

In order to carry out the assessment of the current ecological state of the fish community of this area, a review of the reference state of these communities is required by the FRAI methodology. Many databases of historical information exist today where historical distributions of species can be assessed (Scott *et al.* 2006; Kleynhans *et al.* 2007). These databases where used in this assessment to establish an overview of the historical distribution and possible frequency of occurrence of fishes expected to occur within the study area.

3.4 Habitat assessment

In accordance with the FRAI methodology (Kleynhans, 2005) the habitat assessment for this portion of the study refers to an evaluation of fish habitat potential[1] at a site in terms of the diversity of velocity-depth classes present and the presence of various cover types within each of these velocity-depth classes. This provides a framework within which the presence, absence and frequency of occurrence of species can be interpreted. The habitat assessment includes a general consideration of impacts that may influence the condition or integrity of fish habitat at a site.

3.5 Present Ecological State assessment

In order to establish the Present Ecological State (PES) of the sites assessed in this study the ecological category of the fish community was determined by applying the FRAI methodology using the data collected (desktop and field survey). The procedure for running the FRAI protocol is as follows:

- Planning/preparation (desktop component):
    - Determine the reference conditions (abundance and diversity) for fish communities to occur at each site/reach.
    - Review the general biology of expected fishes to ensure that the sampling methodology implemented in the field will allow for an accurate assessment of the abundance and diversity of fish expected to occur with the study area.
- Carry out a sampling survey:
    - Consider the habitat available for fish to occur within each site/reach prior to sampling to ensure that a confident argument concerning the abundance and diversity of fishes occurring with the study area can be made. Complete the habitat assessment sheets.
    - Sample the current fish abundance and diversity at each site/reach using the pre-established sampling methodology and effort.
    - Collect the observed fish abundance and diversity data.

[1] Habitat potential = potential that the habitat provides suitable conditions for a fish species to live there

- Application of the FRAI model (desktop component):
    - Complete the species occurrence information in the FRAI spreadsheet and consider the species preference/intolerance data to assist with the completion of the metric groups of the FRA assessment.
    - Review any driver information available and the habitat assessment completed in the field by considering the relationships between the driver components and the metric groups (Figure 3).
    - Rank, weight and score each of the metric group components.
    - Consider the impact of introduced (including non-endemic species) or exotic species in the FRAI assessment.
    - Weight the metric groups to provide a fish ecological category for each site/reach assessed.

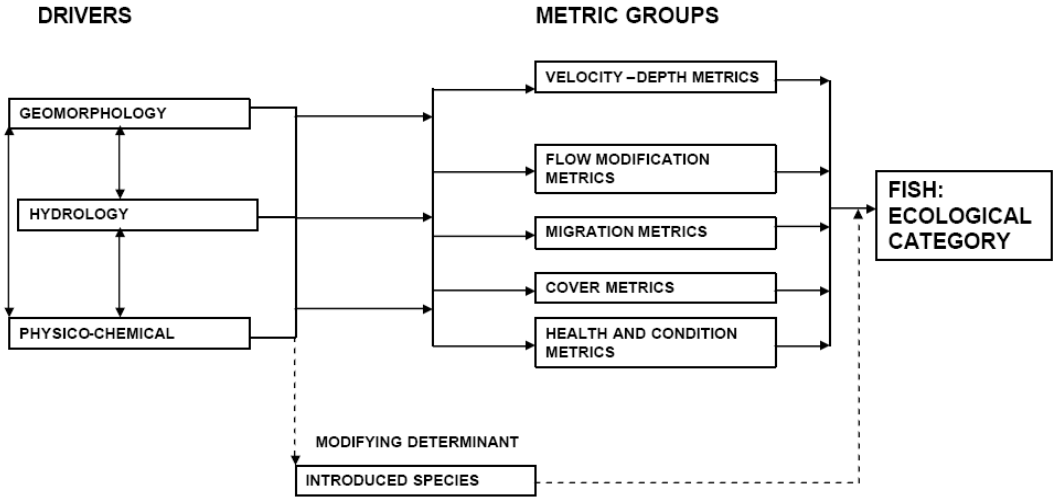

Figure 3: Schematic representation of the Fish Response Assessment Index (FRAI) model

3.6 Interpretation of flow and non-flow related impacts and trajectory of change

Following the assessment of the present ecological state of the fish communities within this study using the FRAI methodology, the reason for a specific fish ecological category (EC) is determined by considering the variables contributing towards the EC, that is, the metric groups that where most impacted resulting in an ecological state that deviates from natural conditions. By unpacking the EC and the metric groups contributing to this EC, an assessment is carried out to establish whether the observed changes in the EC are due to flow or non-flow related impacts. The cause of this deviation in EC is further unpacked to determine which of the metrics are most responsible for the change. From this it is then possible to make recommendations regarding the maintenance or possible improvement of the EC.

3.7 Ecological Importance and Sensitivity assessment

In addition to the core assessment of the ecological state of the fish communities within the study area, an assessment of the ecological importance and sensitivity (EIS) of each site/reach was undertaken. The EIS of each site is determined through a process that involves populating an Excel based EIS model that incorporates fish and invertebrate information related to the potential EIS of the instream and riparian habitats of the system. The model outputs can be viewed in the Annexure 7 of the main report.

3.8 Verification of the modelled EWR estimates

Following the completion of the FRAI and EIS determinations, an assessment of the modelled Environmental Water Requirements (EWR) estimates is undertaken to establish whether or not sufficient provision is made by the EWR estimates to maintain the present EC for fish. This assessment entails an evaluation of the flow requirements of selected species that act as indicator species in relation to the available hydrological and hydraulic habitats provided at each EWR site. This assessment therefore considers the quantity, quality and diversity of critical biotopes in relation to changing flow conditions.

4 RESULTS AND DISCUSSION

This section presents the findings of the assessment of the current ecological state of the fish communities with the study area.

4.1 Site selection

A brief description of the fish habitat, availability and suitability at each of the EWR sites chosen on the Baviaanskloof, Geelhoutbos, Wit, Groot, Gamtoos and Kouga Rivers is provided below.

4.1.1 Upper Baviaanskloof River (BAV1)

The fish habitat at BAV1 was characterised by an abundance of shallow, slow flowing water with associated aquatic macrophytes and overhanging vegetation. Slow flowing deep water was also common. Fish flow-depth habitats and cover types are presented in Table 1.

Table 1: Abundance of each fish habitat flow-depth class and cover type for BAV1

Slow deep	3	Slow shallow	4	Fast deep	1	Fast shallow	2
Overhanging vegetation	3	Overhanging vegetation	3	Overhanging vegetation	3	Overhanging vegetation	3
Undercut banks & root wads	2	Undercut banks & root wads	2	Undercut banks & root wads	0	Undercut banks & root wads	1
Substrate	1	Substrate	1	Substrate	4	Substrate	4
Aquatic macrophytes	2	Aquatic macrophytes	3	Aquatic macrophytes	0	Aquatic macrophytes	1
Water Column	4	Water Column	1	Water Column	3	Water Column	0

4.1.2 Lower Baviaanskloof River (BAV3)

The fish habitat was dominated by slow shallow water with an abundance of overhanging vegetation and aquatic macrophytes at BAV3. Fish flow-depth habitats and cover types are presented in (Table 2).

Table 2: Abundance of each fish habitat flow-depth class and cover type for BAV3

Slow deep	2	Slow shallow	4	Fast deep	0	Fast shallow	2
Overhanging vegetation	4	Overhanging vegetation	4	Overhanging vegetation		Overhanging vegetation	3
Undercut banks & root wads	3	Undercut banks & root wads	3	Undercut banks & root wads	0	Undercut banks & root wads	0

Slow deep	2	Slow shallow	4	Fast deep	0	Fast shallow	2
Substrate	1	Substrate	2	Substrate	0	Substrate	4
Aquatic macrophytes	3	Aquatic macrophytes	4	Aquatic macrophytes	0	Aquatic macrophytes	1
Water Column	4	Water Column	1	Water Column	0	Water Column	1

4.1.3 Geelhoutbos River (GEE1)

The fish habitat at GEE1 is also dominated by slow, shallow water with abundant overhanging vegetation. Undercut banks and root wads are common (Table 3).

Table 3: Abundance of each fish habitat flow-depth class and cover type at GEE1

Slow deep	2	Slow shallow	4	Fast deep	0	Fast shallow	2
Overhanging vegetation	3	Overhanging vegetation	4	Overhanging vegetation	0	Overhanging vegetation	3
Undercut banks & root wads	2	Undercut banks & root wads	3	Undercut banks & root wads	0	Undercut banks & root wads	0
Substrate	1	Substrate	1	Substrate	0	Substrate	3
Aquatic macrophytes	0	Aquatic macrophytes	0	Aquatic macrophytes	0	Aquatic macrophytes	0
Water Column	3	Water Column		Water Column	0	Water Column	

4.1.4 Wit River (WIT1)

The fish habitat was dominated by shallow, slow flowing water. The common cover type for this habitat was overhanging vegetation and substrate (Table 4).

Table 4: Abundance of each fish habitat flow-depth class and cover type at WIT1

Slow deep	2	Slow shallow	4	Fast deep	0	Fast shallow	2
Overhanging vegetation	4	Overhanging vegetation	3	Overhanging vegetation		Overhanging vegetation	3
Undercut banks & root wads	1	Undercut banks & root wads	0	Undercut banks & root wads		Undercut banks & root wads	0
Substrate	3	Substrate	3	Substrate		Substrate	4
Aquatic macrophytes	0	Aquatic macrophytes	0	Aquatic macrophytes		Aquatic macrophytes	0
Water Column	1	Water Column	0	Water Column		Water Column	0

4.1.5 Groot River (GRO1)

Fish habitat flow-depth classes and cover types are presented in Table 5 which indicates that areas of slow shallow flow were abundant and those of slow deep water were common.

Table 5: Abundance of each fish habitat flow-depth class and cover type at GRO1

Slow deep	3	Slow shallow	4	Fast deep	1	Fast shallow	2
Overhanging vegetation	2	Overhanging vegetation	2	Overhanging vegetation	3	Overhanging vegetation	2
Undercut banks & root wads	0	Undercut banks & root wads	1	Undercut banks & root wads	0	Undercut banks & root wads	0
Substrate	1	Substrate	1	Substrate	4	Substrate	4
Aquatic macrophytes	2	Aquatic macrophytes	2	Aquatic macrophytes	0	Aquatic macrophytes	0
Water Column	3	Water Column	1	Water Column	3	Water Column	1

4.1.6 Gamtoos River (GAM1)

The fish habitat at GAM1 varies between abundant slow, shallow water and common slow, deep and fast deep water. The cover type over the slow, shallow water was commonly overhanging vegetation and aquatic macrophytes. The fish habitat flow-depth classes and cover types are presented in Table 6.

Table 6: Abundance of each fish habitat flow-depth class and cover type at GAM1

Slow deep	3	Slow shallow	4	Fast deep	3	Fast shallow	2
Overhanging vegetation	2	Overhanging vegetation	3	Overhanging vegetation	1	Overhanging vegetation	2
Undercut banks & root wads	0	Undercut banks & root wads	0	Undercut banks & root wads	0	Undercut banks & root wads	0
Substrate	1	Substrate	1	Substrate	3	Substrate	4
Aquatic macrophytes	3	Aquatic macrophytes	3	Aquatic macrophytes	1	Aquatic macrophytes	1
Water Column	4	Water Column	1	Water Column	3	Water Column	1

4.1.7 Upper Kouga River (KOU1)

The fish habitat was dominated by slow, shallow water with slow deep water being common. The most common cover type was overhanging vegetation. The fish habitat flow-depth classes and cover types are presented in Table 7.

Table 7: Abundance of each fish habitat flow-depth class and cover type at KOU1

Slow deep	3	Slow shallow	4	Fast deep	1	Fast shallow	2
Overhanging vegetation	2	Overhanging vegetation	3	Overhanging vegetation	1	Overhanging vegetation	2
Undercut banks & root wads	1	Undercut banks & root wads	0	Undercut banks & root wads	0	Undercut banks & root wads	1

Slow deep	3	Slow shallow	4	Fast deep	1	Fast shallow	2
Substrate	2	Substrate	2	Substrate	3	Substrate	4
Aquatic macrophytes	0	Aquatic macrophytes	0	Aquatic macrophytes	0	Aquatic macrophytes	0
Water Column	4	Water Column	0	Water Column	3	Water Column	1

4.1.8 Lower Kouga River (KOU2)

The fish habitat flow-depth classes and cover types are presented in Table 8. This indicates that slow, shallow flowing water was very abundant with slow, deep water being abundant. The dominant cover type for the fish habitat was overhanging vegetation.

Table 8: Abundance of each fish habitat flow-depth class and cover type for KOU2

Slow deep	4	Slow shallow	5	Fast deep	2	Fast shallow	2
Overhanging vegetation	3	Overhanging vegetation	4	Overhanging vegetation	1	Overhanging vegetation	2
Undercut banks & root wads	0	Undercut banks & root wads	0	Undercut banks & root wads	0	Undercut banks & root wads	1
Substrate	1	Substrate	2	Substrate	4	Substrate	4
Aquatic macrophytes	2	Aquatic macrophytes	1	Aquatic macrophytes	0	Aquatic macrophytes	0
Water Column	3	Water Column	1	Water Column	3	Water Column	1

4.1.9 Site suitability assessment

Information used to conduct the site suitability assessment was collected as part of the River Health Programme site assessment conducted for each EWR site (see Annexure 1 for the complete site assessment of each site). The confidence in the suitability of the EWR sites for providing indicators for the verification of the DSS output from 0 (no confidence) to 5 (high confidence). Table 9 provides details on the fish habitat availability and suitability at each EWR site.

Table 9: EWR site suitability for providing clues during field verification

EWR Component	Conf. Level	Advantages	Disadvantages
BAV1			
Fish	3	Site provides access to a diverse range of habitats that are representative of the reach of the river assessed. Although unnatural, the low water bridge at this site provides additional habitat which was sampled in this study. The occurrence of extensive root wads over deep pools provided ideal habitats for fishes. Good water clarity allowed for visual observations of fish communities.	Due to time constraints only a rapid fish sampling assessment was undertaken. Frequent use of the low water bridge may disturb fishes in the area and as such the community structures available for assessment may be altered. Low conductivities affected effectively of electrofishing sampling techniques.

EWR Component	Conf. Level	Advantages	Disadvantages
BAV3			
Fish	3	Site provides access to a diverse range of habitats that are representative of the reach of the river assessed. Good water clarity allowed for visual observations of fish communities.	Due to time constraints only a rapid fish sampling assessment was undertaken. The river crossing at this site is a ford which may be avoided by fishes particularly when used by vehicles. Low conductivities affected effectively of electrofishing sampling techniques.
GEE1			
Fish	3	Site provides access to a diverse range of habitats that are representative of the reach of the river assessed. The occurrence of extensive root wads over deep pools provided ideal habitats for fishes. Good water clarity allowed for visual observations of fish communities.	Due to time constraints only a rapid fish sampling assessment was undertaken. Low conductivities affected effectively of electrofishing sampling techniques.
WIT1			
Fish	3	Site provides access to a diverse range of habitats that are representative of the reach of the river assessed. Although unnatural, the low water bridge at this site may provide additional habitat which was sampled in this study. The occurrence of extensive root wads over deep pools provided ideal habitats for fishes. Good water clarity allowed for visual observations of fish communities.	Due to time constraints only a rapid fish sampling assessment was undertaken. Frequent use of the low water bridge may disturb fishes in the area and as such the community structures available for assessment may be altered. Low conductivities affected effectively of electrofishing sampling techniques.
GRO1			
Fish	2	Site provides access to a diverse range of habitats that are representative of the reach of the river assessed. Although unnatural, the low water bridge at this site may provide additional habitat which was sampled in this study. Deep water areas were diverse and effectively sampled using Fyke nets and Gill nets.	Due to time constraints only a rapid fish sampling assessment was undertaken. Low conductivities affected effectively of electrofishing sampling techniques. Poor water clarity did not allow for any visual observations.
GAM1			
Fish	2	Site provides access to a diverse range of habitats that are representative of the reach of the river assessed. Although unnatural, the low water bridge at this site may provide additional habitat which was sampled in this study	Due to time constraints only a rapid fish sampling assessment was undertaken. Low conductivities affected effectively of electrofishing sampling techniques. Poor water clarity did not allow for any visual observations.
KOU1			
Fish	2	Site provides access to a diverse range of habitats that are representative of the reach of the river assessed. Although unnatural, the low water bridge at this site may provide additional habitat which was sampled in this study	Due to time constraints only a rapid fish sampling assessment was undertaken. Low conductivities affected effectively of electrofishing sampling techniques. Poor water clarity did not allow for any visual observations.
KOU2			
Fish	2	Site provides access to a diverse range of habitats that are representative of the reach of the river assessed. Although unnatural, the low water bridge at this site may provide additional habitat which was sampled in this study	Due to time constraints only a rapid fish sampling assessment was undertaken. Low conductivities affected effectively of electrofishing sampling techniques. Poor water clarity did not allow for any visual observations.

4.2 Data collection

The raw fish data collected in this assessment is presented in the appendix (APPENDIX TABLE). The data collected during the assessment was used along with additional specialist input to complete the Fish Response Assessment Index (FRAI) where applicable (Kleynhans, 2005). Table 10 presents the findings of the FRAI assessment. Findings indicate that the ecological state of rivers assessed ranges of from an "A" or natural state to a "D" or largely modified state. In general, a contrast between the diversity of fishes that occur between sites/reaches assessed seems to be based on the presence of non-endemic or exotic species. Where these species were observed the diversity of indigenous species was noticeably reduced. In addition, the relative abundance of fish observed, assessed as catch per unit effort, decreased (except for the lower Baviaanskloof River Site – BAV3) at sites that contained exotic or non-endemic species. Findings of this assessment suggest that the impact of exotic or non-endemic species is severe. Endemic species seem to have been out-competed or predated out of areas where non-endemic [specifically Bass (*Micropterus spp.*)] species occur. Historical assessments highlight the potential threat that these species pose to indigenous fauna, particularly fishes in the streams of the Western and Eastern Cape of South Africa (Skelton, 1990). In this assessment the occurrence of non-endemic species and exotic species appear to have severely affected the natural fish community structures at the following sites:

- Lower Baviaanskloof River Site (BAV3)
- Gamtoos River Site (GAM1)
- Groot River Site (GRO1)
- Kouga River Sites (KOU1, KOU2 and KOU3)

Table 10: Results of the FRAI assessment including abundance, diversity and catch per unit effort

	Site number	Baviaanskloof River		Baviaanskloof River		Bokkraal River	Gamtoos	Geelhoutbos River		Groot River		Kouga River	Kouga River	Kouga River	Tributary of Kouga Dam	Wit River	
		1	Hist	3	Hist	1	1	1	Hist	1	Hist	1	2	3	1	1	Hist
	Species	**Abr.**															
Species diversity and abundance	*Anguilla mossambica*	AMOS	-		-		-	-	-		5		-	-	-	-	-	
	Gilchristella aestuaria	GAES	-		-		-	1200	-		8		-	-	-	-	-	
	Barbus pallidus	BPAL	16	x	-	x	-	4	-		27	x	-	-	3	2	2	x
	Labeo umbratus	LUMB	-		-		-	-	-		21		-	-	-	-	-	
	Pseudobarbus asper	PASP	-		-		-	-	-		-		-	-	-	-	-	
	Pseudobarbus sp. 'afer cf. Gamtoos'	PAFE	1000	x	-	x	100	-	1000	x	-		-	-	-	18	40	x
	Myxus capensis	MCAP	-		-		-	-	-		-		-	-	-	-	-	
	Sandelia capensis	SCAP	3	x	-		3	-	20		3		-	-	-	2	11	
	Micropterus dolomieu	MDOL	-	?	1	?	-	-	-		1		6	1	1	-	-	x
	Micropterus punctulatus	MPUN	-		-		-	-	-		-		-	1	-	-	-	
	Tilapia sparrmanii	TSPA	-	x	1000	x	-	-	-	x	2	x	-	-	-	-	-	x
	Glossogobius callidus	GCAL	-		-		-	4	-		3	x	-	-	-	-	-	
	Clarias gariepinus	CGAR	-		-		-	1	-		2		-	4	3	-	-	
Total diversity	Total indigenous /endemic species		3	3	0	2	2	3	2	1	6	2	0	0	0	3	3	3
	Total non-endemic/exotic species		0	1-2	2	1-2	0	1	0	1	3	1	1	3	3	0	0	1
CPUE	Total abundance		1019	-	1001	-	103	1209	1020	-	81	-	6	6	7	22	53	-
	Effort (number of efforts used)		1	-	2	-	1	2	1	-	6	-	4	4	1	1	1	-
	CPUE (Total abundance/Effort)		1019	-	500.5	-	103	605	1020	-	13.5	-	1.5	1.5	7	22	53	-

Findings further suggest (Figure 4) that two main sources of exotic and non-endemic fish species exist, the Kouga Dam and private agriculture dams in the upper catchment of the Kouga River. The Kouga Dam is believed to currently maintain a large abundance of Bass, Sharptooth Catfish and Banded Tilapia which have access into the Kouga system and the southern portion of the Baviaanskloof River. The upper reaches of the Kouga River appear to contain a large population of Bass and Catfish species which have accidentally and possibly purposely been released into the Kouga River for primarily what appears to be angling purposes. These sources of exotics and non-endemic species of fishes are contributing to the maintenance of these fishes throughout the Kouga River catchment upstream of the Kouga Dam wall. In the larger tributaries of the Kouga River and the lower Baviaanskloof River where the exotic and non-endemic invaders have established themselves, isolated populations of indigenous fishes currently still occur above geographical barriers which restrict the movement of the exotic and non-endemic species. It is in the opinion of the specialists involved in this assessment that should no mitigation measures be taken to conserve the remaining isolated populations of indigenous fishes in this study area these remaining populations will further be reduced to a point where the extinction of indigenous fishes within this catchment could occur.

Figure 4: Proposed distribution of exotic and non-endemic fishes within the study area[2]

4.2.1 Information availability assessment

Availability of information for the fish component is rated from 0 to 4 (Table 11). A score of 0 to 2 indicates that the level of information is adequate for an RERM, while a score of 3 indicates that it is adequate for an IERM and a score of 4 that it is adequate for a CERM. The confidence levels indicate the confidence of the specialists in the information available. A confidence rating of 5 is high whereas a score of 0 indicates no confidence.

Table 11: Assessment of the information availability for all the study sites

EWR component	Confidence Level	Information availability					Comments
		0	1	2	3	4	
BAV1							
Fish	3			x			Sufficient information exists from previous ichthyofaunal assessments to comprehensively assess the change from reference species assemblages to current assemblages. This site is suitably located within the reach to confidently assess the ecological health f the fish communities within this portion of the river.

[2] No entry signs represent barriers to these exotics and question marks (?) indicate tributary areas where the occurrence of non-endemic and or exotic fishes may occur.

EWR component	Confidence Level	Information availability					Comments
		0	1	2	3	4	
BAV3							
Fish	3			x			Sufficient information exists from previous ichthyofaunal assessments to comprehensively assess the change from reference species assemblages to current assemblages. This site is suitably located within the reach to confidently assess the ecological health f the fish communities within this portion of the river.
GEE1							
Fish	3			x			Sufficient information exists from previous ichthyofaunal assessments to comprehensively assess the change from reference species assemblages to current assemblages. This site is suitably located within the reach to confidently assess the ecological health f the fish communities within this portion of the river.
WIT1							
Fish	3			X			Sufficient information exists from previous ichthyofaunal assessments to comprehensively assess the change from reference species assemblages to current assemblages. This site is suitably located within the reach to confidently assess the ecological health f the fish communities within this portion of the river.
GRO1							
Fish	3			X			Sufficient information exists from previous ichthyofaunal assessments to comprehensively assess the change from reference species assemblages to current assemblages. This site is suitably located within the reach to confidently assess the ecological health f the fish communities within this portion of the river.
GAM1							
Fish	2		X				Although sufficient information exists to confidently address the fish community structures of this site from historical information pertaining to the fish communities of the system, this is the first time an assessment has been undertaken at this site.
KOU1							
Fish	2			X			Sufficient information exists from previous ichthyofaunal assessments to comprehensively assess the change from reference species assemblages to current assemblages. This site is suitably located within the reach to confidently assess the ecological health f the fish communities within this portion of the river.
KOU2							
Fish	2			x			Sufficient information exists from previous ichthyofaunal assessments to comprehensively assess the change from reference species assemblages to current assemblages. This site is suitably located within the reach to confidently assess the ecological health f the fish communities within this portion of the river.

4.3 Reference conditions and biological requirements of fishes within the study area

This component of the study made extensive use of two sources of historical data to assess the change in the reference diversity and abundance of fishes within the study area (Scott *et al.* 2006; Kleynhans *et al.* 2007). Findings are presented in Table 12 and Figure 5 to Figure 9. Table 12 presents the diversity of all fishes expected to occur within the study area. This table indicates that two indigenous species (Smallscale Redfin and the Gamtoos Eastern Cape Redfin) are listed as red data species on the IUCN Red Data list as endangered species, which affords both species with international conservation status. As a result, the active management or conservation of these species is of importance to local, regional and international ecosystem managers.

Table 12: Expected fish species for the study area including their current IUCN category listing[3]

Order	Family	Taxon	Common name	Taxon abr.	IUCN Category	Criteria
Anguilliformes	Anguillidae	*Anguilla mossambica*	Longfin eel	AMOS	Least Concern	
Clupeiformes	Clupeidae	*Gilchristella aestuaria*	Estuarine roundherring	GAES	Least Concern	
Cypriniformes	Cyprinidae	*Barbus pallidus*	Goldie Barb	BPAL	Least Concern	
Cypriniformes	Cyprinidae	*Labeo umbratus*	Moggel	LUMB	Least Concern	
Cypriniformes	Cyprinidae	*Pseudobarbus asper*	Smallscale redfin	PASP	Endangered	B2ab(ii,iii,v)
Cypriniformes	Cyprinidae	*Pseudobarbus sp. 'afer cf. Gamtoos'*	Gamtoos esaterncape redfin	PAFE	Endangered	B2ab(ii,iii,v)
Mugiliformes	Mugilidae	*Myxus capensis*	Freshwater mullet	MCAP	Least Concern	
Perciformes	Anabantidae	*Sandelia capensis*	Cape kurper	SCAP	Data Deficient	
Cyprinodontiformes	Centrarchidae	*Micropterus dolomieu*	Smallmouth bass	MDOL	Exotic	
Cyprinodontiformes	Centrarchidae	*Micropterus punctulatus*	Spotted bass	MPUN	Exotic	
Perciformes	Cichlidae	*Tilapia sparrmanii*	Banded tilapia	TSPA	Non endemic to area	
Perciformes	Gobiidae	*Glossogobius callidus*	River goby	GCAL	Least Concern	
Siluriformes	Clariidae	*Clarias gariepinus*	Sharptooth catfish	CGAR	Non endemic to area	

By carrying out this assessment a brief review of the distribution of species occurring within the study area is made available. The review of indigenous species (Figure 5 to Figure 7) presents the known historical distribution (coloured spots), observed distribution (coloured stars) and remaining sites where species were not observed or expected (black stars) and sites where species were expected but not observed (red stars). Figure 8 presents the distribution of indigenous but non-endemic "alien" fishes occurring in the study area with the observed distribution (red stars) and remaining sites where species were not observed (black stars) indicated. Finally Figure 9 presents the distribution of exotic "alien" fishes occurring in the study area with the observed distribution (red stars) and remaining sites where species were not observed (black stars) indicated.

[3] Scott *et al.* 2006

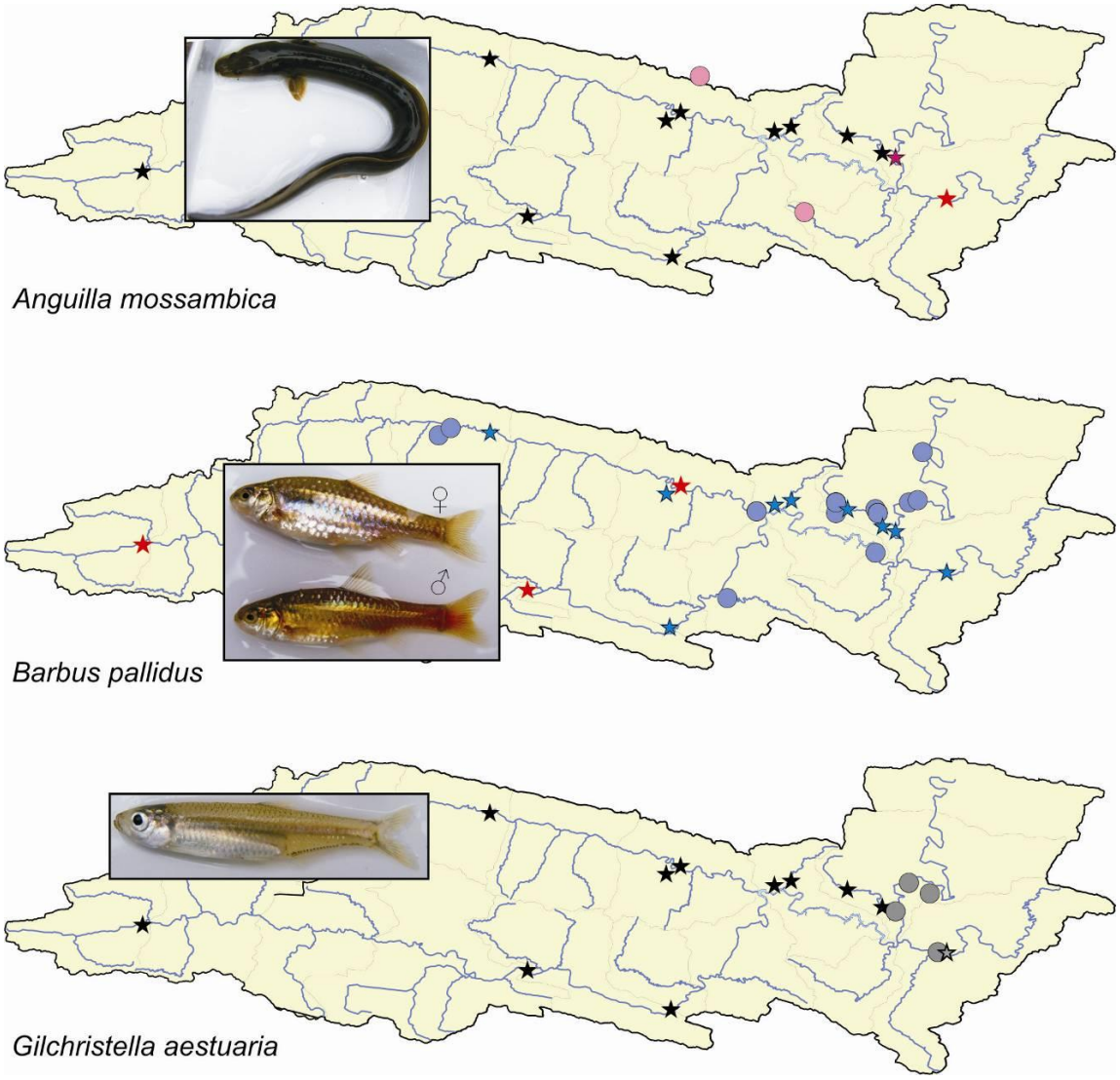

Figure 5: Spatial distribution of indigenous fishes occurring in the study area[4].

[4] Known historical distribution (coloured spots), observed distribution (coloured stars), sites where species were not observed or expected (black stars) and where species were expected but not observed (red stars)

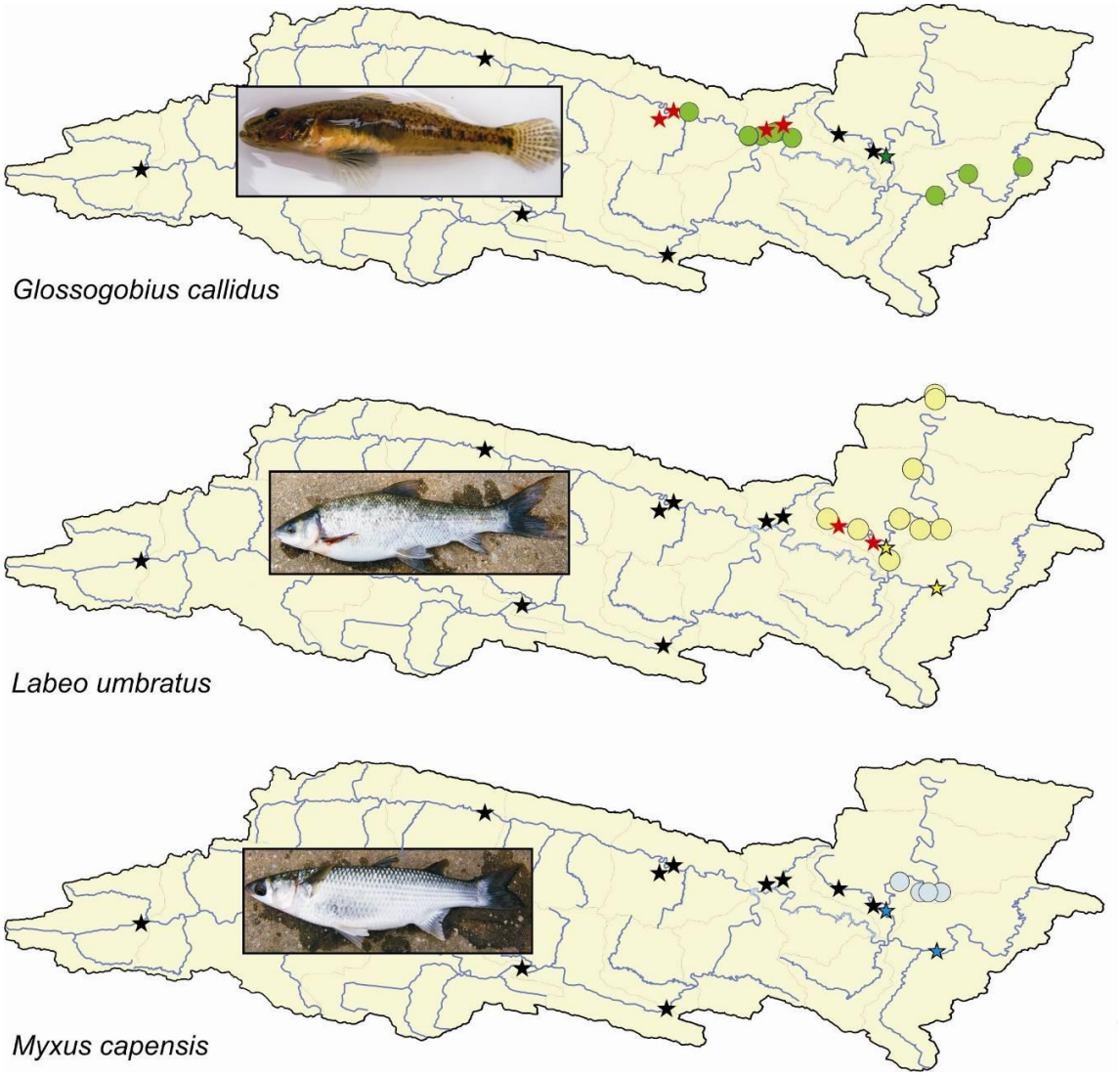

Figure 6: Continuation of the spatial distribution of indigenous fishes occurring in the study area[5]

[5] Known historical distribution (coloured spots), observed distribution (coloured stars), sites where species were not observed or expected (black stars) and where species were expected but not observed (red stars)

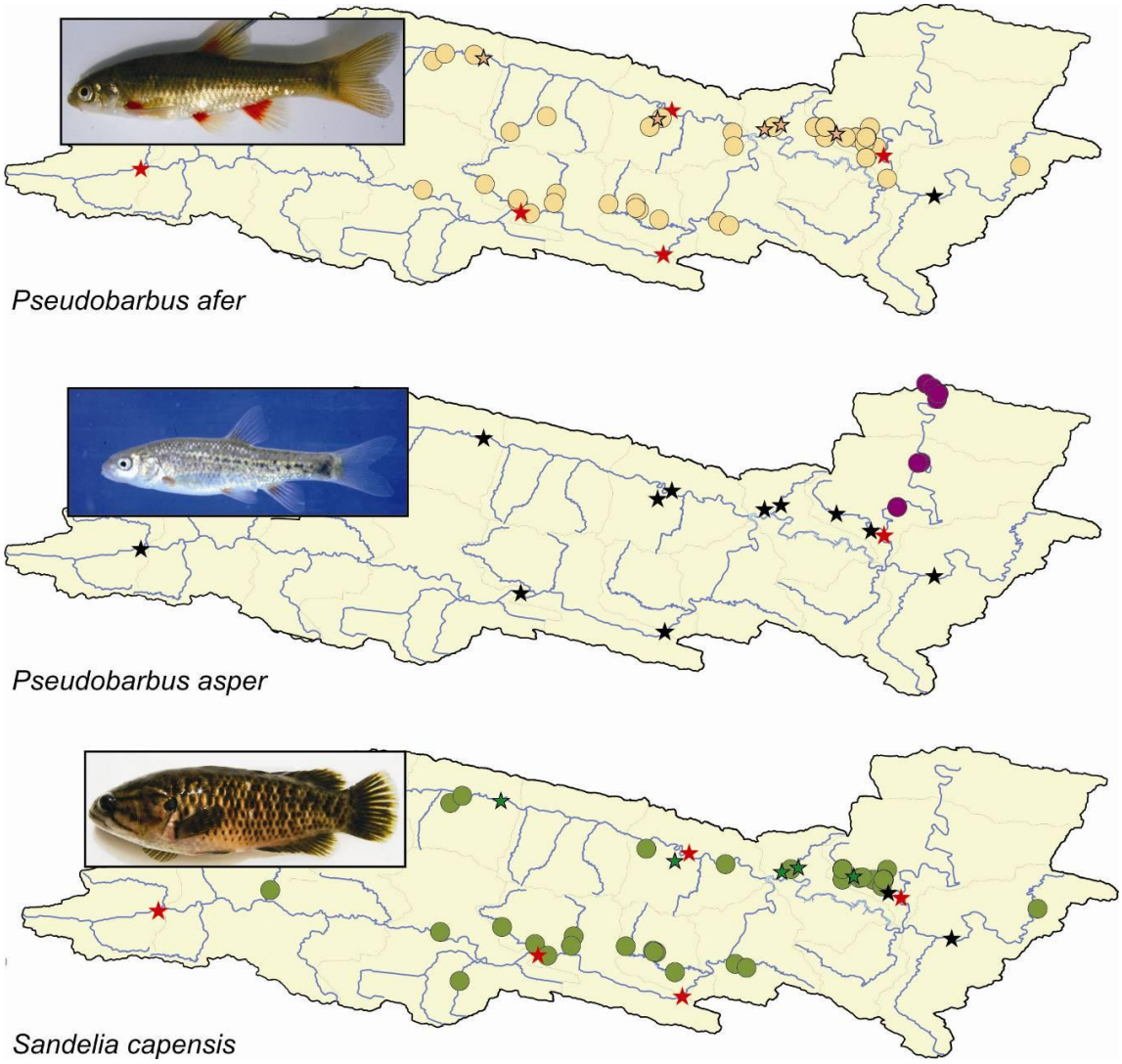

Figure 7: Continuation of the spatial distribution of indigenous fishes occurring in the study area[6]

[6] Known historical distribution (coloured spots), observed distribution (coloured stars), sites where species were not observed or expected (black stars) and where species were expected but not observed (red stars) indicated.

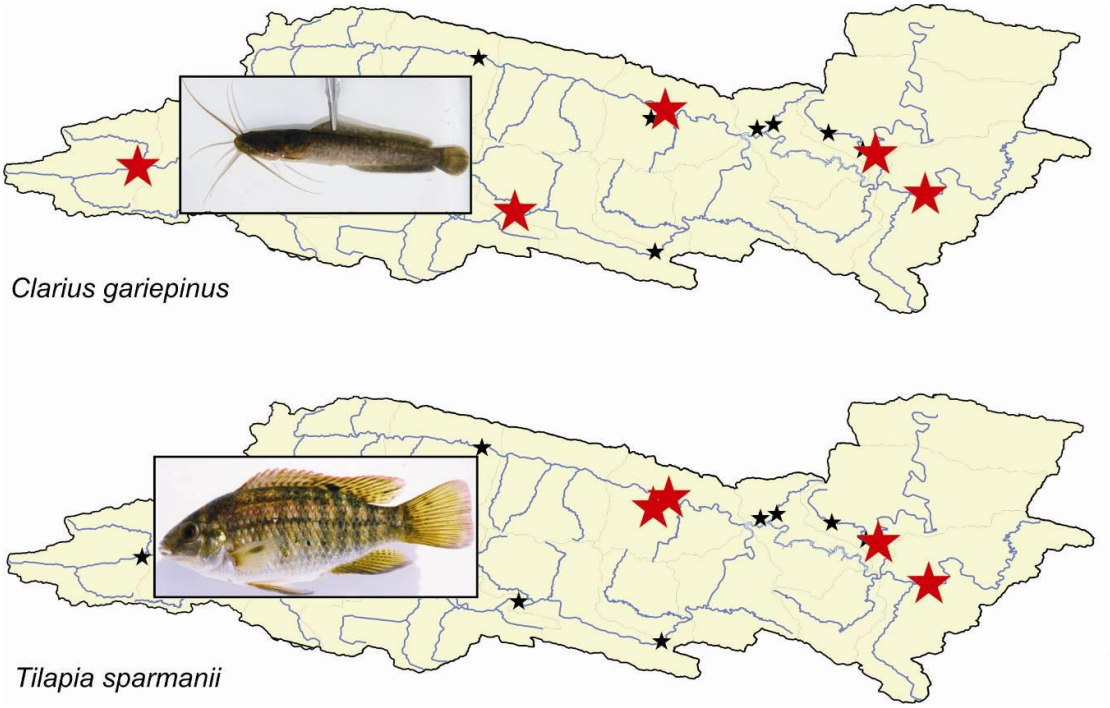

Figure 8: Spatial distribution of indigenous non-endemic alien fishes occurring in the study area[7]

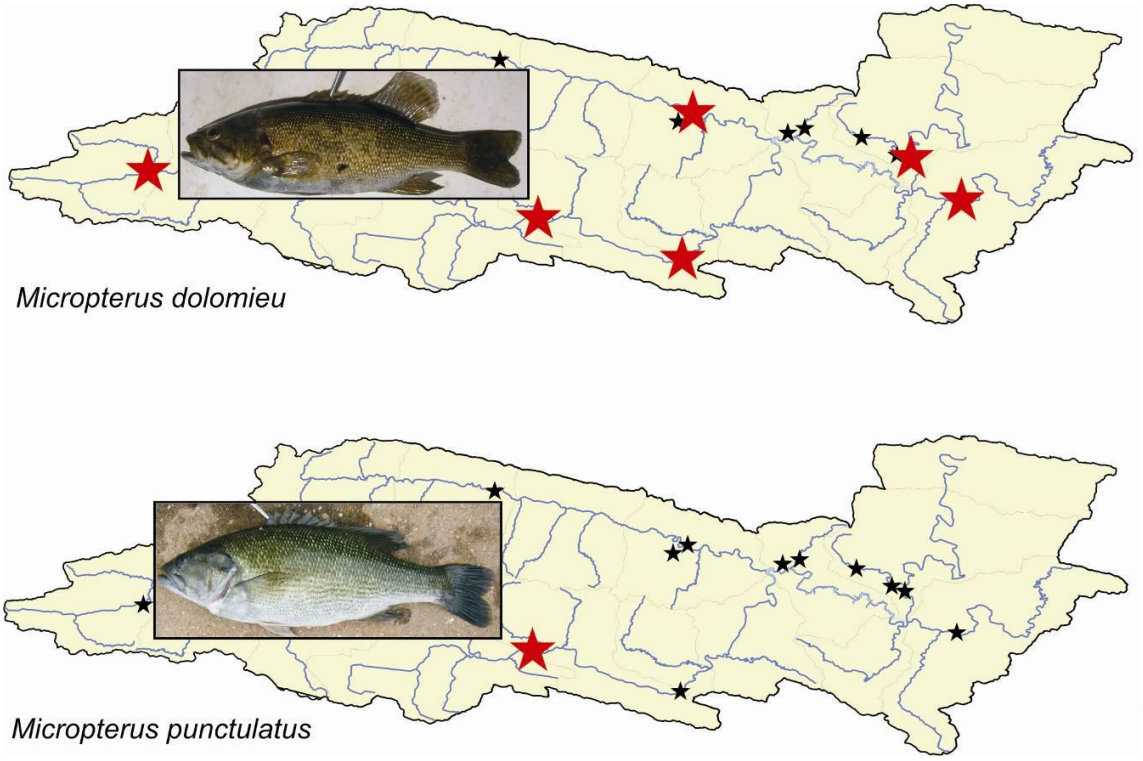

Figure 9: Spatial distribution of exotic alien fishes occurring in the study area

[7] Observed distribution (red stars), sites where species were not observed (black stars)

Table 13 presents an overview of the biological preferences/tolerances of species to environmental variable conditions (adapted from Kleynhans, 2005). This information provides valuable information relating to the ability of a species to survive certain changes in environmental conditions.

Table 13: Review of the biological preferences/tolerances of species to environmental variables

Species		Flow-depth					COVER					Migration	
		PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	FLOW TOLERANCE	BANK UNDERCUT	SUBSTRATE	AQUATIC MACROPHYTES	WATER COLUMN	WATER QUALITY TOLERANCE	Migration requirements	Distance migrating (km)
Anguilla mossambica	AMOS	3.40	3.30	3.40	-	2.80	4.10	4.90	-	-	2.50	5.00	Up to watershed, >100km
Gilchristella aestuaria	GAES	-	-	3.50	3.70	1.50	-	-	-	4.50	3.00	3.00	0-20
Barbus pallidus	BPAL	-	-	-	3.80	2.80	-	3.50	-	-	3.30	1.00	Very local movement
Labeo umbratus	LUMB	-	-	4.50	-	2.70	-	4.20	-	-	1.60	1.00	0.00
Pseudobarbus asper	PASP	-	-	4.00	4.00	5.00	4.00	4.00	4.00	-	3.00	1.00	20-100km
Pseudobarbus afer	PAFE	-	-	4.00	3.50	4.00	4.00	4.00	4.00	-	3.50	1.00	0-20km
Myxus capensis	MCAP	-	-	3.80	-	3.50	-	-	-	3.80	3.00	3.00	50-120km
Sandelia capensis	SCAP	-	-	-	3.70	2.00	-	3.50	4.50	-	2.00	1.00	<1km
Micropterus dolomieu	MDOL	3.30	-	4.60	-	1.00	3.40	3.60	3.20	-	2.60	Exotic/non-endemic species	
Micropterus punctulatus	MPUN	4.00	-	3.50	-	1.00	-	4.00	-	4.00	3.00	Exotic/non-endemic species	
Tilapia sparrmanii	TSPA	-	-	-	4.30	0.90	-	-	3.60	-	1.40	Exotic/non-endemic species	
Glossogobius callidus	GCAL	-	-	-	4.70	1.50	-	4.90	-	-	2.30	1.00	Local
Clarias gariepinus	CGAR	-	-	4.30	3.40	1.70	-	-	-	-	1.00	Exotic/non-endemic species	

Note: Tolerance guide to no flow conditions include:

>4 = Intolerant of no flow conditions
3-4 = Moderately intolerant of no flow conditions
2-3 = Moderately tolerant of no flow conditions
1-2 = Tolerant of no flow conditions

Tolerance guide to modified water quality conditions include:

>4 = Intolerant to modified water quality conditions
3-4 = Moderately intolerant to modified water quality conditions
2-3 = Moderately tolerant to modified water quality conditions
1-2 = Tolerant to modified water quality conditions

Migration requirement guide:

5 = Catchment scale migrations
3 = Movement between reaches / fish habitat segments
1 = Movement within reaches / fish habitat segments

4.3.1 Review of changes in the reference state of indigenous fishes in the study area

Within the study area, the distribution of the Longfin eel (*A. mossambica*) was expected to be restricted and this species was observed in high abundances at one site alone (Groot River Site) (Figure 5 and Table 13). The only additional site where this species was expected to occur due to its ability to migrate over large areas, but were not observed was in the Gamtoos River which acts as a conduit for this catadromic species' movement upstream into the Groot River. Due to the record of this species upstream of the Gamtoos River site and the absence of barriers it is assumed that this species does occur at this site. Only large barriers such as the Kouga Dam wall act as barriers which now restrict the movement of this species into the upper reaches of the study area. The Goldie barb (*B. pallidus*) occurs throughout the study area and remains the most widely distributed of the indigenous fishes in the study area (Figure 5). This locally isolated, species which prefers slow flowing waters is the only indigenous species that appears to remain in the Kouga River upstream of the Kouga Dam. Although only three specimens where recorded at KOU3 the presence of these individuals indicate that the total removal of indigenous species from the Kouga River system has not occurred.

This species is considered to be more advanced in comparison to the other small cyprinid species which occur within this catchment (*Pseudobarbus spp.*) and may have the biological traits to maintain themselves in the presence of exotic predators such as the Bass which are abundant in this system. In addition the distribution of this species includes the Vaal and Orange River catchment which contains many predatory species including large cyprinids and the Sharptooth Catfish. Of all the sites assessed in this study this species was expected but not observed at three sites. All three sites contain large abundances of exotic or non-endemic species which do suggest that these species are impacted on by the presence of these invasive species. Similarly to the Longfin eel, the Estuarine roundherring (*G. aestuaria*) (Figure 5), the Freshwater goby (*G. callidus*) and the Freshwater mullet (*M. capensis*) (both in Figure 6) are all either catadromic species or estuarine dependant species which dominate estuaries within the area and migrate upstream into freshwater reaches of systems during their life cycles. As expected these species were recorded in the Gamtoos and Groot rivers and where excluded from all other sites in the study area primarily due to geological barriers. The occurrence of large abundances of these species at the Groot and Gamtoos river sites where exotic and non-endemic species occur indicates that although there is evidence to suggest that these species migrating species are predated upon by the non-endemic species (Figure 10 and Weyl & Lewis, 2005) observed in the study they may be able to maintain populations in these systems. This co-existence may change in the future and it is recommended that this relationship be monitored into the future.

Figure 10: Sharptooth catfish (~2kg) attempting to consume a large (over 1kg) freshwater mullet[8]

One of the interesting finds in this study was the collection of 21 individual Moggels (*L.umbratus*) in the Groot River alone (

[8] Photograph by author taken in a KwaZulu-Natal Estuary

Figure 6). This species is more commonly known in the Orange-Vaal River catchment (similarly to the Goldie barb) and as a result has rarely been researched in the Gamtoos Catchment.
Each population of this species (Orange-Vaal River population and this population) is currently isolated from one another and some research into the differences between the species is due to be initiated by the South African Institute for Aquatic Biodiversity (SAIAB) in the near future. Genetic samples and voucher specimens of this species where collected, preserved and delivered to SAIAB to facilitate any future research into this species. This species, believed to be a herbivore, has a high preference for slow deep areas and requires a specific substrate for spawning purposes (Skelton, 2001 and Table 13). As previously indicated, the two Redfin Minnows that occur within the study area both have international conservation status. In South Africa as a whole, of the seven Redfin Minnows that occur, five have conservation status. The main driving variables which have contributed to the decline of these fishes primarily includes the over-utilization of the systems in which these species occur and predation by Bass (Skelton, 2001). In this survey no Smallscale Redfin Minnow (*P. asper*) where observed but were expected at the Groot River site, and the Eastern Cape Redfin Minnow (*P. afer*) (Figure 7) was only obtained from areas that did not contain any exotic or non-endemic predatory fishes. Both of these species prefer the slow habitats and are intolerant of no flow conditions. Both species have high cover requirements and are moderately intolerant to modified water quality changes. Noticeable differences between the biology of the species do exist including the migration potential of the species where the Smallscale Redfin Minnows migrates over considerably larger distances (20-120km) than the Gamtoos Eastern Cape Redfin Minnow which generally only moves with a local reach (within 20km) (Table 13). Another important difference is that the Smallscale Redfin Minnow occurs in water arising from the Karoo which is generally acidic in comparison to the Gamtoos Eastern Cape Redfin Minnow which generally occurs within the more alkaline waters of the Eastern Cape streams (*Pers. Comm.* D. Impson[9]). This survey only considered the lower distribution of the Smallscale Redfin Minnow population in the Groot River which extends out of the study area northwards into the Karoo. This may be the reason why no individuals of this species where obtained in this study. Another possibility is that this species does not have the ability to co-exist with non-endemic predators and that they may have been successfully eradicated by bass in the lower reaches of the Groot River where Bass are common. The inclusion of future sites in the Groot River upstream of the study area is important to ascertain the cause for this species not occurring within the study area. Where under natural conditions the Gamtoos Eastern Cape Redfin Minnow population would have dominated the fish communities throughout the study area, under current conditions their distribution has been fragmented and depleted to isolated populations in areas above barriers to non-endemic predators that now occur within the study area. Due to the current fragmented state of these populations, this species is under high risk of becoming extinct due to the following:

- these populations are isolated from one another,
- they have lost most of their natural habitat,
- the isolated populations are highly susceptible to environmental impacts that may affect some of the isolated areas,
- the barriers keeping the predators out of these areas may be removed such as would be the case if a prolonged high flow condition is maintained in the upper Baviaanskloof River resulting in the upper section of the river reconnecting above ground with the lower section of the system.

Finally, the last indigenous species that occurs within this study area is the Cape Kurper (*S. capensis*) (Figure 7). This hardy species is a local resident that prefers slow-shallow habitats and has a high preference for substrate and aquatic macrophytes. Although considered to be hardy this species is susceptible to predation by non-endemic predatory species such as Bass

[9] Dean Impson (22nd of October 2008) Cape Nature

and the Sharptooth Catfish. Along with the Gamtoos Eastern Cape Redfin Minnow, findings of this study indicate that the natural distribution of this species has been severely reduced, and that this species cannot co-exist with non-endemic predatory fishes such as Bass.

4.3.2 Review of changes in reference conditions due to exotic or non-endemic species

The two non-endemic (Figure 8)but indigenous species of fishes which have become invasive in the study area are the Sharptooth Catfish (*C. gariepinus*) and the Banded Tilapia (*T. sparmanii*). These species may have been actively stocked into dams for angling purposes within the study area including the Kouga Dam and/or they may have accidentally been washed from farm dams that overflow or have broken, into the Kouga System. Both of these species compete with local indigenous species and both have the potential to predate on local indigenous species, specifically the juveniles of the indigenous species. The Sharptooth catfish is a very hardy species that can tolerate highly polluted conditions including very low oxygen (<1mg/l) levels. This species even has the ability to migrate out of drying pools overland into adjacent pools. This suggests that this species will eventually be able to migrate above most barriers in the Gamtoos system and will have an impact on most of the indigenous population of fishes in the system. The Sharptooth catfish grows very rapidly and is an omnivorous scavenger that can be maintained in a system with a limited food sources. This species is persistent and difficult to eradicate. The Banded Tilapia is a modern cichlid which has become a good bait species for Bass throughout Southern Africa. This species, possibly released into the Kouga River as a fodder species for Bass, is an aggressive breeder that out-competes local species for space when breeding and feeds of juvenile minnows and Cape Kurper offspring. The occurrence of these species in the study area poses a threat to the continued survival of the indigenous species that occur in this area. Figure 9 presents the distribution of the two predatory Bass species that occur within the study area. Of the two, the Smallmouth Bass (*M. dolomieu*) is more common and poses a greater threat to the indigenous species than the Stripped Bass (M. punctulatus). Both species can be attributed with the loss in the distribution of the indigenous Goldie Barb, Cape Kurper and the Redfin minnows. Urgent management actions are required to address the impact posed to the system by these species.

4.4 Present Ecological State

A synopsis of the ecological state assessment findings (application of the FRAI model) are presented in Table 14 and Table 15. Findings of the automated FRAI assessment indicate that the current ecological state of the sites assessed in the system range between a class “B” and a Class “F”. The automated assessment attributes the reduction in species abundance and diversity to modifications in the water quality, flow (timing, volume and duration) and habitat state of the sites which is the main consideration of the metric components of the FRAI model.

By adjusting the evaluations (adjusted FRAI assessment) the current state of the driver components (water quality, flow and habitat) can be addressed. The scores (adjusted FRAI assessment) for each metric contributing to state of the EC at each EWR site as well as the weight or relative importance allocated to each metric, is presented in Figure 11 and Figure 12 respectively. Findings indicate that the true state (adjusted FRAI assessment scores) of the ecosystem range between “A” or pristine state and “D” or largely modified. It must however, be taken into consideration that the *main stressor* impacting on the fish community state in this study are the impacts of *non-endemic fish species*.

As a result the outcomes of the FRAI assessment are skewed towards addressing the conservation issue of managing the exotic species and not the ecosystem resource issue of managing the diver components of the system (such as flow, water quality and habitat). In this study wherever natural diversities of fishes occur, the assessment indicates that these sites compare to natural/close to natural or pristine conditions. At these sites (Baviaanskloof River 1,

Bokkraal River 1, Geelhoutbos River 1 and the Tributary of the Kouga Dam 1) the driving components of the system are considered to be acceptable as conditions allow for the maintenance of all of the fish species that occur within these areas.
At the Groot and Gamtoos river sites the state of the fish communities are in a "B/C" and "C" or slightly modified state respectively. The fish communities at these sites include numerous indigenous, non-endemic and exotic species. The contributing impact of modified driver component states and the predatory impact of non-endemic species have resulted in the modified state of the system.

The current ecological state of the Baviaanskloof River site 3 is a "C" or slightly modified state. This portion of the Baviaanskloof River contains two non-endemic species and the negative impact of these species has resulted in the complete eradication of the indigenous fish communities at this site. As such it was not possible to confidently assess the contributions made by the modified driver components to the state of this reach. Modifications to velocity-depth, flow, cover, physico-chemical and migration metrics where made according to the available ecosystem use scenarios.

Finally all three Kouga River sites where assessed together as one reach. The findings indicate that the fish community in this reach is in a "D" or largely modified state. Once again this state can be attributed primarily to the impacts of the non-endemic fishes on the endemic fish community. Within this reach the occurrence of the Goldie Barbs (at Kouga Site 3) were used in the assessment of the state of the driver components. In general the scores (adjusted FRAI assessment) for metrics contributing to the present state (EC) (Figure 11) indicate that the main stressors impacting on the natural fish community structure and function are the impacts of alien fishes and barriers impacting on the migration of species. Only at the Kouga River and Gamtoos River sites do some of the other driver components contribute to an impacted EC state. As a result, the metric considering the risk posed to the system by alien fishes is awarded with the highest importance/weighting (Figure 12), followed by the water-quality metric which is considered to be the second most important variable to manage in the study area.

Although the findings indicate that the migration metric is often in an impaired state (sites usually above the Kouga Dam) this has not resulted in a large deviation of the fish community structures and as such is awarded with a low weight/importance in determining the EC (Figure 12). Table 16 highlights the main probable causes for the present state (PES) of the fish communities at all EWR sites and whether or not these are flow related. The results are given a confidence rating of between 5 and 0 where 5 indicates high confidence and of 0 indicates no confidence.

Table 14: Results of the FRAI assessment, including metric scores and weightings

		Site number	Baviaanskloof River 1	Baviaanskloof River 3	Bokkraal River	Gamtoos	Geelhoutbos River	Groot River	Kouga River 1 Kouga River 2 Kouga River 3	Tributary of Kouga Dam	Wit River
FRAI	Automated	Score	83.3	-12.3	86.8	62.63	83.3	73.4	10.8	87.2	83.7
		Class	B	F	B	C	B	C	F	B	B
	Adjusted	Score	90.5	72.6	95.8	76.4	92.3	78.7	56.8	95.8	92.3
		Class	A/B	C	A	C	A	B/C	D	A	A
Metric scores	Changes in commonness of velocity-depth classes		0	1.43	0	12.86	0	7.14	7.86	0	0
	Changes in commonness of fish cover classes		0	0	0	21.7	0	5.7	33.1	0	0
	Flow Modifications		0	5.88	0	14.12	0	5.29	9.41	0	0
	Physico-chemical modifications		0	7.7	0	15.4	0	3.8	7.7	0	0
	Changes in system connectivity		38.5	38.5	38.5	0	38.5	0	56.9	38.5	38.5
	Impact of introduced species		30.5	100	30.5	60	20.5	100	100	0	20.5
Weight of scores	Velocity-depth		44.4	40.0	44.4	58.5	44.4	61.9	37.8	44.4	44.4
	Cover		48.9	44.0	48.9	51.2	48.9	52.4	35.6	48.9	48.9
	Flow modification		51.1	46.0	51.1	56.1	51.1	52.4	28.9	51.1	51.1
	Physico-chemical		71.1	54.0	71.1	70.7	71.1	73.8	64.4	71.1	71.1
	Migration		26.7	24.0	26.7	29.3	26.7	16.7	62.2	26.7	26.7
	Impact of introduced species		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 15: Description of the PES for each of the EWR sites based on the FRAI outputs

EWR Site	PES	Metrics	Indicator taxa/values	Narrative	Conf. Level
BAV1	**A/B**	Velocity-depth	*P. afer*	Velocity depth, cover, flow modification, physico-chemical metrics considered to be in a natural state. Only migration impacts and risk of exotic species impacting on community structure evident. Risk of exotic species impacting on this isolated community results in weight of introduced species dominating assessment.	3
		Cover	Community		
		Flow modification	*P. afer*		
		Physico-chemical	*P. afer* and *B. pallidus*		
		Migration	Community		
		Impact of Introduced species	None		
		FRAI Score	90.5		
BAV3	**C**	Velocity-depth	*P. afer*	Cover, flow modification, physico-chemical metrics considered to be in a natural state. Here velocity depth habitat modifications and impact of introduced species evident. Exotic species have entirely removed community of indigenous fishes. Severity of impact not indicated here with FRAI as driving components of concern (Water quality, habitat and flow) are in suitable states. Conservation intervention required to manage exotics.	3
		Cover	Community		
		Flow modification	*P. afer*		
		Physico-chemical	*P. afer* and *B. pallidus*		
		Migration	Community		
		Impact of Introduced species	*Micropterus spp.*		
		FRAI Score	72.6		
GEE1	**A**	Velocity-depth	*P. afer*	Velocity depth, cover, flow modification, physico-chemical metrics considered to be in a natural state. Only migration impacts and risk of exotic species impacting on community structure evident. Risk of exotic species impacting on this isolated community results in weight of introduced species dominating assessment.	3
		Cover	Community		
		Flow modification	*P. afer*		
		Physico-chemical	*P. afer*		

EWR Site	PES	Metrics	Indicator taxa/values	Narrative	Conf. Level
		Migration	Community		
		Impact of Introduced species	None		
		FRAI Score	92.3		
WIT1	**A**	Velocity-depth	*P. afer*	Velocity depth, cover, flow modification, physico-chemical metrics considered to be in a natural state. Only migration impacts and risk of exotic species impacting on community structure evident. Risk of exotic species impacting on this isolated community results in weight of introduced species dominating assessment.	3
		Cover	Community		
		Flow modification	*P. afer*		
		Physico-chemical	*P. afer* and *B. pallidus*		
		Migration	Community		
		Impact of Introduced species	None		
		FRAI Score	92.3		
GRO1	**B/C**	Velocity-depth	*P. afer*	Minimal impacts affecting velocity depth, cover, flow modifications and physical chemical metrics. Impacts of introduced species severe. Connectivity intact allowing migration of catadromic species. Conservation intervention required to manage exotics.	3
		Cover	Community		
		Flow modification	*Pseudobarbus spp.* and *A. mossambica*		
		Physico-chemical	*P. afer* and *B. pallidus*		
		Migration	Community (NB *A. mossambica* and *M. capensis*).		
		Impact of Introduced species	*Micropterus spp.*		
		FRAI Score	78.7		
GAM1	**C**	Velocity-depth	*P. afer*	Moderate impacts affecting velocity depth, cover, flow modifications and physical chemical metrics. Impacts of introduced species severe. Connectivity intact allowing migration of catadromic species. Conservation intervention required to manage exotics.	3
		Cover	Community		
		Flow modification	*Pseudobarbus spp.* and *A. mossambica*		
		Physico-chemical	*P. afer* and *B. pallidus*		
		Migration	Community (NB *A. mossambica* and *M. capensis*).		
		Impact of Introduced species	*Micropterus spp.*		
		FRAI Score	76.4		
KOU1&2	**D**	Velocity-depth	*P. afer*	Moderate impacts affecting velocity depth, cover, flow modifications and physical chemical metrics. Impacts of introduced species severe. Connectivity removed not allowing migration of catadromic species. Severity of impact related to predation by exotic species not indicated here with FRAI as driving components of concern (Water quality,	3
		Cover	Community		
		Flow modification	*P. afer*		
		Physico-chemical	*P. afer* and *B. pallidus*		

EWR Site	PES	Metrics	Indicator taxa/values	Narrative	Conf. Level
		Migration	Community	habitat and flow) are in suitable states. Conservation intervention required to manage exotics.	
		Impact of Introduced species	*Micropterus spp.*		
		FRAI Score	56.8		

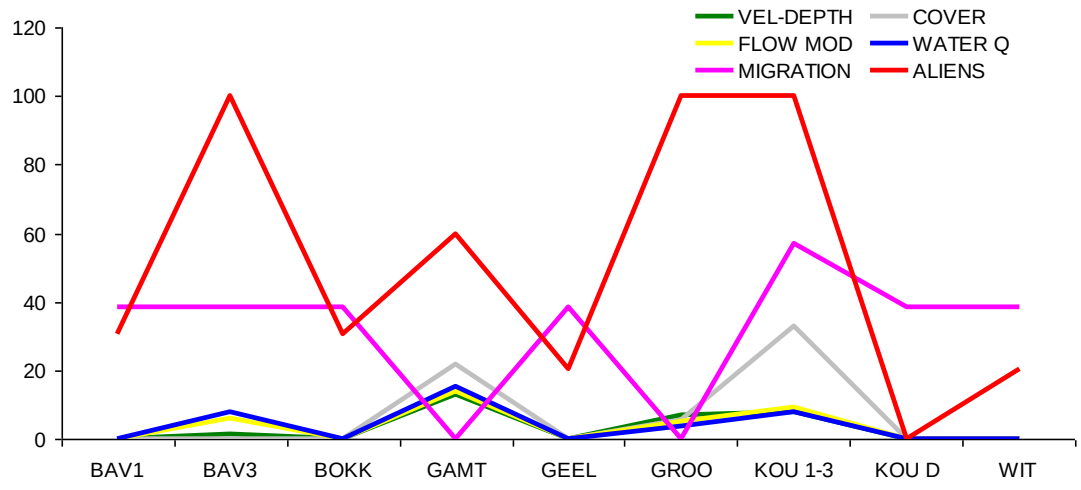

Figure 11: Final FRAI scores (deviation from natural) of each metric (coloured lines) for all sites

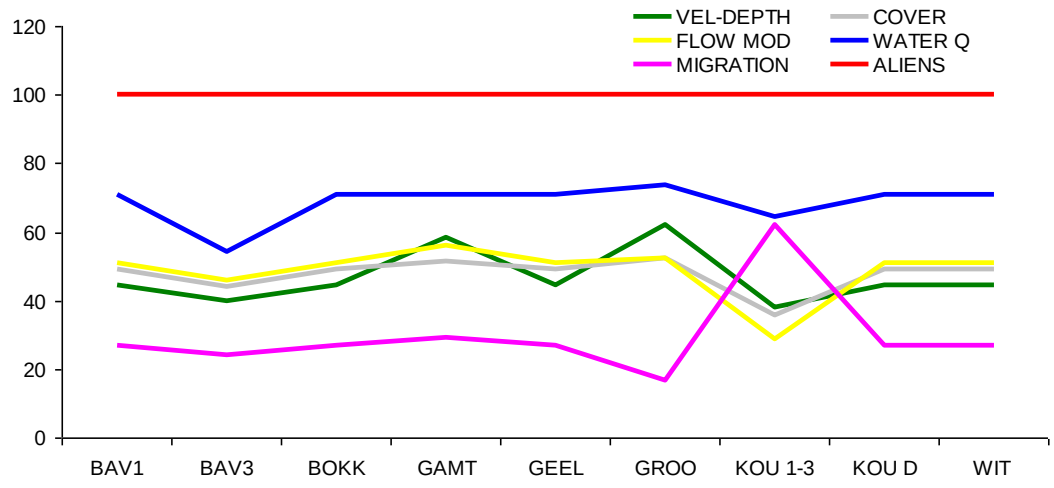

Figure 12: Weights allocated to the final FRAI scores of each metric (coloured lines) for all sites

Table 16: PES category for the biophysical components of BAV1 with reasons for the PES

EWR Site	PES	Causes of the PES	Sources of the PES	F/NF[10]	Conf. Level
BAV1	A/B	Risk of aliens impacting on the refuge area	Exotics below barrier at BAV 3	NF	2
		Habitat alteration	Low water bridge construction	NF	2
BAV3	C	Aliens impacting on the refuge area	Alien species introduced into Kouga Dam	NF	2
		Habitat alteration	Low water bridge construction	NF	2
		Flow timing and duration	Agricultural activities	F	2
		Water quality	Agricultural activities	NF	2
		Migration	Kouga Dam removing connectivity.	NF	2
GEE1	A	Risk of aliens impacting on the refuge area	Exotics below barrier at BAV 3	NF	2
		Habitat alteration	Low water bridge construction	NF	2
WIT1	A	Risk of aliens impacting on the refuge area	Exotics below barrier at GRO1	NF	2
		Habitat alteration	Low water bridge construction	NF	2
GRO1	B/C	Aliens impacting on the refuge area	Alien species introduced into Groot River	NF	2
		Habitat alteration	Low water bridge construction, development of riparian areas.	NF	2
		Flow timing and duration	Agricultural activities	F	2
		Water quality	Agricultural activities	NF	2
GAM1	C	Aliens impacting on the refuge area	Alien species introduced into Gamtoos River	NF	2
		Habitat alteration	Low water bridge construction, development of riparian areas.	NF	2
		Flow timing and duration	Agricultural activities	F	2
		Water quality	Agricultural activities	NF	2
KOU1&2	D	Aliens impacting on the refuge area	Alien species introduced into Kouga Dam	NF	2
		Habitat alteration	Low water bridge construction, development of riparian areas.	NF	2
		Flow timing and duration	Agricultural activities	F	2
		Water quality	Agricultural activities	NF	2

4.4.1 Trend in the PES

The trend (direction of change from reference condition) in the PES is assessed and the results are given a confidence rating from 1 (low confidence) to 5 (high confidence). Trend is considered under the current condition of land and water use. It aims to assess whether the fish have already adapted to the existing anthropogenic impacts or whether human induced / unnatural change and adjustment in the fish community is still taking place.

[10] Flow or Non Flow related causes of the PES

The analysis of the PES trend furthermore aims to highlight possible risk areas to the current PES if negative. A stable trend is indicative of an ecosystem that is not declining or improving while a positive trend signifies and ecosystem that is in the process of improving and a negative trend one that is declining.

Table 17 present the trends allocated to each site as well as the reasoning behind the allocation. The "Trend PES" gives an indication of the severity of the anticipated improvement or decline (trend) in the medium term (5 years).

Table 17: PES trend for fish component with reasons for the trend

EWR site	PES	%EC	Trend	Trend PES	Conf. Level	Reasons for the trend
BAV1	A/B	90.5	↓	C	2	Existence of barrier maintaining refugia area from contamination by exotics dependent on maintenance of strict flow regime management . Recent trends indicate that a risk of barrier becoming inundated is high.
BAV3	C	72.6	↔	C	2	Limited alteration in drivers is expected. Exotic species have already successfully removed endemic communities of fishes.
GEE1	A	92.3	↓	C	2	Existence of barrier maintaining refugia area from contamination by exotics dependent on maintenance of strict flow regime management. Recent trends indicate that a risk of barrier becoming inundated is high.
WIT1	A	92.3	↓	C	2	Existence of barrier maintaining refugia area from contamination by exotics dependent on maintenance of strict flow regime management. Recent trends indicate that a risk of barrier becoming inundated is high.
GRO1	B/C	78.7	↓	C	2	Slight continued alteration in drivers is expected. Exotic species are affecting endemic communities of fishes, which is considered to worsen.
GAM1	C	76.4	↓	D	2	Moderate continued alteration in drivers is expected. Exotic species are affecting endemic communities of fishes, which is considered to worsen.
KOU1&2	D	56.8	↔	D	2	Slight continued alteration in drivers is expected. Exotic species have already successfully removed endemic communities of fishes.

4.4.2 Ecological Importance and Sensitivity

The ecological sensitivity refers to the river's ability to recover from disturbance. The Excel based EIS model (Kleynhans 1999) was used to assess the ecological importance and sensitivity under present conditions. Table 18 presents the integrated EcoStatus results as well as the results of the EIS assessment for the Baviaanskloof, Geelhoutbos, Wit, Groot, and Kouga Rivers. The scoring, reasoning and confidence levels are presented in Annexure 7.

4.4.3 Integrated EcoStatus

Present ecological state (PES) assessments of the various biophysical components are integrated into an overall ecological classification or EcoStatus score using the EcoStatus Level III Excel-based model (Kleynhans, 1999). The EcoStatus score can be modified by the Ecological Importance and Sensitivity (EIS) assessment to give the final recommended ecological category (REC) if desirable and feasible. E.g. if the resource is degraded (i.e. has a low PES) but has a HIGH Ecological Importance and Sensitivity (EIS), the EC should ideally be upgraded if it is potentially feasible to do. Table 18 presents the results of the integrated EcoStatus assessment for each EWR site assessed. The scoring, reasoning and confidence levels are presented in Annexure 9.

Table 18: Integrated EcoStatus for all sites, including the PES trend, EIS and REC

SITE	QUAT	Present Ecological State		EIS	TREND		REC
		EC	%EC		5yr	10yr	
BAV1	L81B	B/C	80.94	HIGH	N	S-P	B
BAV3	L81D	B/C	77.48	HIGH	N	S-P	B
GEE1	L81D	A/B	91.04	HIGH	S	S	A
WIT1	L70G	A/B	90.74	HIGH	S	S	A
GRO1	L70G	C	74.44	HIGH	N	S	C
GAM1	L90A	C/D	61.25	HIGH	N	S	C
KOU1	L82A	D	44.23	HIGH	N	S	D
KOU2	L82D	D	54.08	HIGH	N	S	D

4.5 Verification of the modelled Environmental Water Requirement flows

This assessment involves the analysis of the adequacy of EWR flow estimates provided by the SPATSIM model for each REC in terms of the survival of the aquatic invertebrate community. The EWR flow estimates are transformed into hydraulic parameters (depth and velocity) and transposed onto the river cross section profiles. Indicator taxa identified during the FRAI process are primarily used to assess whether or not the EWR estimates will provide the required flow, habitat and water quality conditions for the maintenance of the fish EC determined for each EWR site. The assessment is furthermore primarily based on the comparison between the average velocities and depths attained during the present day assessment of the EC (field survey) and the values of the same parameters calculated for the drought low flow EWR estimates, since these represent the most critical flow period for the fish.

i. Baviaanskloof River upstream (BAV1)

Table 19 represents the hydraulic parameters for the upper Baviaanskloof based on the EWR flow estimates for an REC of B.

Table 19: Hydraulic conditions at BAV1 based on the modelled EWR flows

BAV1	Discharge (m^3/s)	Depth of Flow in Cross-section Profile (m)		Average Velocity (m/s)
		Maximum Depth	Average Depth	
Measured Flow	0.033	0.205	0.127	0.070
Dry season maintenance - January	0.072	0.274	0.196	0.080
Dry season drought - January	0.000	0.000	0.000	0.000
Wet season maintenance – May	0.129	0.349	0.271	0.081
Wet season drought - May	0.000	0.000	0.000	0.000

In terms of the maintenance requirements of the endemic fishes that occur within this reach, apart from the drought flows, there seems to be sufficient flows provided to all species to maintain the community structures that exist here. Due to this reach acting as a refuge area for the endemic fishes of the Baviaanskloof River, against predation from alien fishes that occur below a barrier in the river, should the flow in this reach cease and the pools dry up (modelled drought flows), the endemic fishes of this reach would be totally eradicated as no recruitment from historical refuge areas lower down in the system remains. The Eastern Cape Redfin (*P. afer*) is the most sensitive to no flow conditions of all fishes expected to occur. Apart from the drought flows, of the modelled flows from the measured flows to the wet season flows (May) the depth provided to species should be sufficient to maintain communities, provide spawning

cues and facilitate recruitment into the system. Take note that this site falls within a refugia area for local endemic fishes. At this site the Baviaanskloof River flows on the surface providing habitats for fishes, it then flows beneath the surface for a limited segment establishing a natural barrier to fishes below the barrier. Thereafter it re-surfaces again and is connected with the Kouga Dam which is dominated by alien fishes. The alien fishes that have impacted on the fishes within the Baviaanskloof River extend to this natural barrier.

In addition to the treat of flows ceasing in this refuge area that would result in the eradication of all endemic fishes in this reach, should the barrier be inundated, access to the refugia area by the alien fishes will be established which will again result in the eradication of the endemic fishes of the upper Baviaanskloof River It is thus imperative that this refuge area be continually inundated and that the barrier be maintained until mitigation measured can be established to manage the aliens in the Baviaanskloof River.

ii. Baviaanskloof River downstream (BAV3)

Table 20 represents the hydraulic parameters for the lower Baviaanskloof based on the EWR flow estimates for an REC of B.

Table 20: Hydraulic conditions at BAV3 based on the modelled EWR flows

BAV3	Discharge (m^3/s)	Depth of Flow in Cross-section Profile (m)		Average Velocity (m/s)
		Maximum Depth	Average Depth	
Measure Flow	0.061	0.130	0.068	0.314
Dry season maintenance - January	0.108	0.171	0.126	0.370
Dry season drought - January	0.000	0.000	0.000	0.000
Wet season maintenance - May	0.199	0.227	0.164	0.454
Wet season drought - May	0.000	0.000	0.000	0.000

Currently, no indigenous fishes occur within this reach of the Baviaanskloof River and as such there is no current ecological water requirement to maintain the indigenous fishes of this reach. However, should rehabilitation actions (that are urgently required) be carried out to re-establish endemic populations of fishes in this reach the modelled flows for maintaining this system in a B state are (apart from the drought flows) sufficient to maintain these populations.

Similarly to the assessment of site BAV 1, of all of the indigenous fishes that are expected to occur here, the Eastern Cape Redfin (*P. afer*) is considered to be most sensitive to no flow conditions with a high preference for still pools. Should the flows cease and pools dry up the fishes of this reach would be eradicated starting with the Eastern Cape Redfin. All of the remaining flows should be sufficient to maintain communities, provide spawning cues and facilitate recruitment into the system. In order for the modelled flows of both of the Baviaanskloof River sites to be suitable for this system, refuge areas that were historically available to the indigenous fishes of this reach must be re-established.

It is recommended that an (alien fish) eradication programme be established to remove the alien predators from this system, below the barrier separating BAV 1 and BAV 3 and that a new barrier be established just up stream of the Kouga and Baviaanskloof Rivers to prevent these aliens migrating back into this reach. This would allow for the re-colonisation of the endemic fishes back into the lower portions of the Baviaanskloof River which will act as refuge

areas for these species should the modelled drought flows result in the flow in the upper reaches ceasing. This conservation endeavour should be considered as a matter of urgency.

iii. Wit River (WIT1)

Table 21 represents the hydraulic parameters for the Wit based on the EWR flow estimates for an REC of an A.

Table 21: Hydraulic conditions at WIT1 based on the modelled EWR flows

WIT1	Discharge (m^3/s)	Depth of Flow in Cross-section Profile (m)		Average Velocity (m/s)
		Maximum Depth	Average depth	
Measure Flow	0.038	0.180	0.117	0.078
Dry season maintenance - June	0.039	0.184	0.121	0.078
Dr season drought - June	0.005	0.073	0.049	0.040
Wet season maintenance - September	0.052	0.210	0.147	0.085
Wet season drought - September	0.007	0.085	0.061	0.045

Similarly to the BAV1 site the fish community structures at this site are intact and the species most sensitive to no flow conditions is the Eastern Cape Redfin (*P. afer*). Based on the flow and associated requirements of this species the modelled flows indicated would be adequate to maintain the population of this species at this site. However it appears that in terms of the flow requirements of the fishes that occur within this reach, during the drought periods where the maximum depth of the pools in this reach would be reduced to 0.073m and 0.085m, the endemic fishes would be placed under severe stress resulting in a reduction in the abundance and health of the communities of fishes that occur there. During these periods the remaining communities would be extremely sensitive to other stressors such as habitat alteration and or water quality impacts. Currently there are no threats of water quality and habitat altering stressors occurring in this reach and this should be maintained. It is recommended that the population of this red data species in this reach be monitored should the flows reduce to March drought levels.

iv. Groot River (GRO1)

Table 22 represents the hydraulic parameters for the Groot based on the EWR flow estimates for an REC of a C.

Table 22: Hydraulic conditions at GRO1 based on the modelled EWR flows

GRO1	Discharge (m^3/s)	Depth of Flow in Cross-section Profile (m)		Average Velocity (m/s)
		Maximum Depth	Average Depth	
Measure Flow	0.318	0.210	0.130	0.435
Dry season maintenance - July	0.140	0.383	0.157	0.302
Dry season drought - July	0.011	0.054	0.053	0.186
Wet season maintenance – March	0.930	1.464	0.351	0.602
Wet season drought - March	0.030	0.089	0.081	0.216

Of the fishes that are expected to occur within this reach of the Groot River, only the catadromic Eel that migrates into and beyond this reach of the Groot River has a requirement for fast deep habitats which allows this species to penetrate this portion of the river. Apart from this requirement, the two Redfins (*P. afer* and *P. asper*) that occur here are sensitive to no-flow conditions. The modelled flows are considered to be sufficient to maintain all of the species that occur within this reach during the March maintenance and July maintenance conditions. During the July and March drought conditions it is recommended that the population of the Eels be monitored and that the flows of this system not be allowed to reach no flow conditions.

v. Kouga River downstream (KOU2)

Table 23 represents the hydraulic parameters for the Kouga downstream based on the EWR flow estimates for an REC of a D.

Table 23: Hydraulic conditions at KOU2 based on the modelled EWR flows

KOU2	Discharge (m^3/s)	Depth of Flow in Cross-section Profile (m)		Average Velocity (m/s)
		Maximum Depth	Average Depth	
Measure Flow	2.809	0.850	0.467	0.255
Dry season maintenance – February	0.883	0.495	0.211	0.248
Dry season drought - February	0.054	0.197	0.132	0.278
Wet season maintenance – August	0.684	0.455	0.210	1.503
Wet season drought - August	0.107	0.246	0.123	0.435

Historically the fish community assemblages of this river would have been comparable to that of the Gamtoos River excluding the Smallscale Redfin (*P. asper*) which prefers the slightly more acidic waters of the Groot River. Two main stressors have impacted on the diversity of fishes within this system including the construction of the Kouga Dam which has formed a barrier that has impeded the migration of the catadromic fish species, and the effects of the alien fishes (Bass and the Sharptooth Catfish) that have reduced the distribution of endemic species into pockets of isolated populations predominantly within the upper tributaries of the Kouga River. As a result no indigenous fishes occur within this reach of the Kouga River and as such there is currently no ecological water requirement to maintain the indigenous fishes of this reach. However, should rehabilitation actions be carried out to re-establish endemic populations of fishes in this reach, the modelled flows allocated to maintain this system in a D state are considered to be sufficient to maintain these populations. Of all of the indigenous fishes that are expected to occur here, the Eastern Cape Redfin (*P. afer*) is considered to be most sensitive to no flow conditions and have a high preference for still pools. Maintaining these habitats within the Kouga River is critical to maintaining this species within this system.

4.6 Fish community management measures

Take note that in this assessment the dominant stressor impacting on the ecological state of the fish communities is related to the presence of the exotic and non-endemic fish species that out-compete and predate on local endemic species. In order to address the risk posed to the endemic fish communities within this study area, a management plan for the alien (exotic and non-endemic) fishes should be established. Furthermore, in terms of the maintenance of the EWR specifications, the Kouga River sites and the Baviaanskloof River Site 3 are currently dominated by these non-endemic and exotic fishes and are virtually devoid of endemic fishes.

As such, should the EWR specifications not be adhered to, prior to any rehabilitation actions to address the fish communities in the Kouga River and the lower Baviaanskloof River areas,

only the undesirable fish communities would be affected. However, should rehabilitation actions take place and the local endemic fish communities re-establish themselves, then the EWR specifications for these systems should be maintained to provide endemic species with the ecological cues etc. required to maintain these communities. In the case of Baviaanskloof River Site 1, the Geelhoutbos River site and the Wit River site, local endemic fish populations are intact primarily due to the maintenance of barriers that are restricting the movement of exotic and or non-endemic fish species into these refugia areas.

The fish communities within these isolated areas are extremely sensitive to stressors including flow related stressors. As such the maintenance of the base low flows proposed for these systems to provide the potential ecological cues required by these fishes is a priority as well as the maintenance of the barriers which keep these refugia areas intact. The reaches of the Groot and Gamtoos rivers considered in this study are currently provided with sufficient flow variation to maintain suitable populations of indigenous fishes. Within these reaches the maintenance of suitable EWR specifications should be adhered to, in order to maintain these communities. The consequences of not adhering to the EWR specifications proposed in this study include the risk of many fish species not maintaining their life cycle biology and as a result the losses of these species from this study area.

5 CONCLUSIONS

In conclusion, the current state of the fish communities within the study area varies in accordance with the presence or absence of alien and non-endemic invasive species. In areas where these non-endemic species occur, the indigenous species generally do not occur. The result is the reduction (abundance and distribution) and fragmentation of indigenous fish populations within the study area. The remaining fragmented populations are still threatened by the increasing distribution of non-endemic species into the remaining refugia areas for indigenous species. Apart from the stressors of non-endemic fishes the ability of catadromic species and other catchment scale migratory species in the area (Eel, Freshwater mullet and River goby) has been restricted primarily by the construction of the Kouga Dam. Furthermore, in the Groot, Gamtoos and Upper Kouga rivers, activities such as agricultural farming are altering the state of the driving components of the ecosystem which are in turn impacting on the ecological state of the fish communities within these systems. Although management plans should be established to address the changed ecological driver states, the conservation issue of managing the impact of the alien fish species in this system is considered to be of utmost importance.

The assessment of the implications of the modelled flows for the study, have resulted in the identification of an important risk to the continued survival of the indigenous fishes that occur within the upper Baviaanskloof River. Modelled flows indicate that there is a chance that the flow in the Baviaanskloof River may cease altogether. Under natural conditions or historically, the local populations of endemic fishes would have been eradicated in the Upper Baviaanskloof River during no flow conditions only to be re-established by populations that would have been able to survive these events in pools lower down in river which act as refuge areas. Currently, the lower reaches of the Baviaanskloof River have been occupied by alien predatory fishes that have eradicated the endemic populations of fishes in these areas. By removing the endemic populations of fishes from these “drought flow” refugia areas, should drought conditions in the area occur, there is a risk of these communities becoming extinct as no re-colonisation of endemic fishes being possible.

6 RECOMMENDATION

The true distribution of indigenous fishes in relation to the distribution of the alien species in the entire study area is unknown, due to difficulty accessing some of the areas. In addition, the risk posed by aliens to areas that currently contain large populations of indigenous fish species is

unknown. Following the outcomes of this study recommendations are made to carry out a comprehensive regional scale risk assessment, considering the current distribution of indigenous and/or exotic species and the risk posed by the fish in the contaminated areas to the un-impacted areas. The inclusion of new sites into this assessment has increased the confidence of the study and aided in establishing a scenario of activities. These sites should, where possible, be included into future assessments and additional sites on important systems such as large tributaries of the Kouga River, namely the Dwaas, Braam and Witteklip streams should be included.
It is also recommended that a conservation plan be urgently established to eradicate the alien fishes from the Baviaanskloof River below the barrier that isolates the reaming communities of endemic fishes in the Baviaanskloof River. This conservation action will not only re-connect numerous isolated fragments of communities of endemic fishes that currently occupy the upper reaches of tributaries of the Baviaanskloof River (including the population in the Houtbosloop River) allowing gene flow between these communities, but it will also re-establish the populations of endemic fishes required to persist in the drought flow refuge areas in the lower Baviaanskloof River.

Finally, no recreational activities, such as recreational angling, are permitted in the Kouga Dam. As a result there is no social and ecological value to the alien fish species in this dam. Recommendations are made to consider managing the alien population in the dam such as to minimise the risk posed by the aliens in this dam to the river systems above this dam.

7 MANAGEMENT AND MITIGATION MEASURES

Table 24 presents a detailed summary of the potential impacts on the fish community identified for each river system in the study area as well as the associated management and mitigation measures. Specific objectives for the aquatic macro-invertebrate communities are also provided per river. These specific objectives can be used to inform the setting of Resource Quality Objectives.

Table 24: Possible impacts and associated mitigation measures for maintaining fish community health of rivers within the Baviaanskloof Mega Reserve

EWR component affected	Potential impact	Mitigation measures	Specific objectives
BAVIAANSKLOOF AND GEELHOUTBOS			
Ecological condition	Reduction of biodiversity due to altered drivers of the system including altered water quality, habitat and flows. Loss of ecosystem functions, disruption of structure and function of ecosystem.	Maintain balance between the protection and use of the resource. Establish a conservation plan for red data fish species. Establish a management plan for the alien fish species. Monitor the biodiversity of the system by implementing the National River Health Programme monitoring bi-annually.	• Establish conservation plan for *P. afer* • Establish a management plan for alien fishes.
Riparian & instream habitat	Loss of key habitats required by endemic fishes.	Select an indicator/umbrella fish species that has specific habitat requirements and monitor the community structure of the selected species and the availability and state of key habitats.	• Establish conservation plan for *P. afer*
Water quantity	Significant alteration of the natural flow regime. Loss of refugia areas as a result of the loss of barriers currently maintaining refugia areas and or loss of critical habitats within refugia areas.	Maintain EWR Specifications. Monitor the diversity of endemic fish species and or the occurrence of alien fish species bi-annually. Establish a management plan for the alien fish species.	• Monitor fish diversity bi-annually. • Establish a management plan for alien fishes.
WIT			
Ecological condition	Reduction of biodiversity due to altered drivers of the system including altered water quality, habitat and flows. Loss of ecosystem functions, disruption of structure and function of ecosystem.	Maintain balance between the protection and use of the resource. Establish a conservation plan for red data fish species. Establish a management plan for the alien fish species. Monitor the biodiversity of the system by implementing the National River Health Programme monitoring bi-annually.	• Establish conservation plan for *P. afer* • Establish conservation plan for *P. asper* • Establish a management plan for alien fishes.
Riparian & instream habitat	Loss of key habitats required by endemic fishes.	Select an indicator/umbrella fish species that has specific habitat requirements and monitor the community structure of the selected species and the availability and state of key habitats.	• Establish conservation plan for *P. afer* • Establish conservation plan for *P. asper*
Water quantity	Significant alteration of the natural flow regime. Loss of refugia areas as a result of the loss of barriers currently maintaining refugia areas and or loss of critical habitats within refugia areas.	Maintain EWR Specifications. Monitor the diversity of endemic fish species and or the occurrence of alien fish species bi-annually. Establish a management plan for the alien fish species.	• Monitor fish diversity bi-annually. • Establish a management plan for alien fishes.

EWR component affected	Potential impact	Mitigation measures	Specific objectives
GROOT			
Ecological condition	Reduction of biodiversity due to altered drivers of the system including altered water quality, habitat and flows. Loss of ecosystem functions, disruption of structure and function of ecosystem.	Maintain balance between the protection and use of the resource. Establish a conservation plan for red data fish species. Establish a management plan for the alien fish species. Monitor the biodiversity of the system by implementing the National River Health Programme monitoring bi-annually.	• Establish conservation plan for *P. afer* • Establish conservation plan for *P. asper* • Establish a management plan for alien fishes.
Riparian & instream habitat	Loss of key habitats required by endemic fishes.	Select an indicator/umbrella fish species that has specific habitat requirements and monitor the community structure of the selected species and the availability and state of key habitats.	• Establish conservation plan for *P. afer* • Establish conservation plan for *P. asper*
Water quantity	Significant alteration of the natural flow regime. Disrupted migration of catadromic fish species.	Maintain EWR Specifications. Monitor the diversity of catadromic fishes within the river.	• Monitor use of system by *A. mossambica* • Monitor use of system by *M. capensis* • Monitor use of system by *G. aestuaria*
KOUGA			
Ecological condition	Reduction of biodiversity due to altered drivers of the system including altered water quality, habitat and flows. Loss of ecosystem functions, disruption of structure and function of ecosystem.	Maintain balance between the protection and use of the resource. Establish a conservation plan for red data fish species. Establish a management plan for the alien fish species. Monitor the biodiversity of the system by implementing the National River Health Programme monitoring bi-annually.	• Establish conservation plan for *P. afer* • Establish a management plan for alien fishes.
Riparian & instream habitat	Loss of key habitats required by endemic fishes.	Select an indicator/umbrella fish species that has specific habitat requirements and monitor the community structure of the selected species and the availability and state of key habitats.	• Establish conservation plan for *P. afer*
Water quantity	Significant alteration of the natural flow regime. Loss of refugia areas in tributaries as a result of the loss of barriers currently maintaining refugia areas and or loss of critical habitats within refugia areas.	Maintain EWR Specifications. Monitor the diversity of endemic fish species and or the occurrence of alien fish species bi-annually. Establish a management plan for the alien fish species.	• Monitor fish diversity bi-annually. • Establish a management plan for alien fishes.

EWR component affected	Potential impact	Mitigation measures	Specific objectives
GAMTOOS			
Ecological condition	Reduction of biodiversity due to altered drivers of the system including altered water quality, habitat and flows. Loss of ecosystem functions, disruption of structure and function of ecosystem.	Maintain balance between the protection and use of the resource. Establish a conservation plan for red data fish species. Establish a management plan for the alien fish species. Monitor the biodiversity of the system by implementing the National River Health Programme monitoring bi-annually.	• Establish conservation plan for *P. afer* • Establish conservation plan for *P. asper* • Establish a management plan for alien fishes.
Riparian & instream habitat	Loss of key habitats required by endemic fishes.	Select an indicator/umbrella fish species that has specific habitat requirements and monitor the community structure of the selected species and the availability and state of key habitats.	• Establish conservation plan for *P. afer* • Establish conservation plan for *P. asper*
Water quantity	Significant alteration of the natural flow regime. Disrupted migration of catadromic fish species.	Maintain EWR Specifications. Monitor the diversity of catadromic fishes within the river.	• Monitor use of system by *A. mossambica* • Monitor use of system by *M. capensis* • Monitor use of system by *G. aestuaria*

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APPENDIX TABLE

Appendix Table: Review of the fish data sampled during the October 2008 fish sampling survey undertaken by the study team.

Date	Project	System	Site	Samplers	Effort	Sampling method	Effort	GPS °S	GPS °E	SD	SS	FS	FD	Species abr	No.
20-Oct	Baviaans	Wit River	1		1	Electroshock - SAMUS	6min	-33.660550	24.534880	40	60	0	0	PAFE	40
20-Oct	Baviaans	Wit River	1		1	Electroshock - SAMUS	6min	-33.660550	24.534880	40	60	0	0	BPAL	2
20-Oct	Baviaans	Wit River	1		1	Electroshock - SAMUS	6min	-33.660550	24.534880	40	60	0	0	SCAP	11
20-Oct	Baviaans	Wit River	1		1	Electroshock - SAMUS	6min	-33.660550	24.534880	40	60	0	0	TSPA	1
20-Oct	Baviaans	Groot River	1		1	Electroshock - SAMUS	5min	-33.695290	24.611700	20	50	0	30	TSPA	2
20-Oct	Baviaans	Groot River	1		1	Electroshock - SAMUS	5min	-33.695290	24.611700	20	50	0	30	BPAL	3
20-Oct	Baviaans	Groot River	1		1	Electroshock - SAMUS	5min	-33.695290	24.611700	20	50	0	30	GCAL	3
20-Oct	Baviaans	Groot River	1		1	Electroshock - SAMUS	5min	-33.695290	24.611700	20	50	0	30	AMOS	1
20-Oct	Baviaans	Groot River	1		2	Gill net - 50mm mesh	2hrs	-33.695290	24.611700	90	10	0	0	LUMB	15
20-Oct	Baviaans	Groot River	1		2	Gill net - 50mm mesh	2hrs	-33.695290	24.611700	90	10	0	0	MCAP	3
20-Oct	Baviaans	Groot River	1		2	Gill net - 50mm mesh	2hrs	-33.695290	24.611700	90	10	0	0	MDOL	1
20-Oct	Baviaans	Groot River	1		3	Fyke Net (x2 medium)	3hrs	-33.695290	24.611700	80	20	0	0	LUMB	6
20-Oct	Baviaans	Groot River	1	Gordon O'Brien, Dean Impson, DWAF, Cape Nature and EC parks teams	3	Fyke Net (x2 medium)	3hrs	-33.695290	24.611700	80	20	0	0	GAES	8
20-Oct	Baviaans	Groot River	1		3	Fyke Net (x2 medium)	3hrs	-33.695290	24.611700	80	20	0	0	BPAL	7
20-Oct	Baviaans	Groot River	1		3	Fyke Net (x2 medium)	3hrs	-33.695290	24.611700	80	20	0	0	CGAR	2
21-Oct	Baviaans	Kouga River	2		1	Fyke Net (x2 medium)	2hrs	-33.788420	24.025300	80	20	0	0		0
21-Oct	Baviaans	Kouga River	2		2	Gill net - 50mm mesh	2hrs	-33.788420	24.025300	80	20	0	0		0
21-Oct	Baviaans	Kouga River	2		3	Electroshock - SAMUS	15min	-33.788420	24.025300	30	40	10	20	CGAR	4
21-Oct	Baviaans	Kouga River	2		3	Electroshock - SAMUS		-33.788420	24.025300	30	40	10	20	MDOL	1
21-Oct	Baviaans	Kouga River	2		4	Fly-fishing	6wt - 30min	-33.788420	24.025300	100	0	0	0	MDOL	1
21-Oct	Baviaans	Kouga River	1		1	Fyke Net (x2 medium)	2hrs	-33.716610	23.411330	90	10	0	0	MSAL	6
22-Oct	Baviaans	Kouga River	1		2	Electroshock - SAMUS	10min	-33.716610	23.411330	10	30	10	50		0
24-Oct	Baviaans	Baviaanskloof River	1		1	Scoop - Landing net	25 Scoops	-33.537890	23.965110	80	20	0	0	BPAL	16
24-Oct	Baviaans	Baviaanskloof River	1		1	Scoop - Landing net	26 Scoops	-33.537890	23.965110	80	20	0	0	PAFE	1000
24-Oct	Baviaans	Baviaanskloof River	1		1	Scoop - Landing net	27 Scoops	-33.537890	23.965110	80	20	0	0	SCAP	3
24-Oct	Baviaans	Baviaanskloof River	3		1	Snorkel	30min	-33.622870	24.269280	40	60	0	0	TSPA	1000
24-Oct	Baviaans	Baviaanskloof River	3		1	Snorkel	30min	-33.622870	24.269280	40	60	0	0	MSAL	1
24-Oct	Baviaans	Baviaanskloof River	3		1	Snorkel	30min	-33.622870	24.269280	40	60	0	0	CGAR	1

24-Oct	Baviaans	Baviaanskloof River	3		2	Electroshock - SAMUS	5min	-33.622870	24.269280	40	60	0	0		0
25-Oct	Baviaans	Geelhoutbos River	1		1	Electroshock - SAMUS	5min	-33.635710	24.246070	10	80	0	10	SCAP	20
25-Oct	Baviaans	Geelhoutbos River	1		1	Electroshock - SAMUS	5min	-33.635710	24.246070	10	80	0	10	PAFE	1000
25-Oct	Baviaans	Geelhoutbos River	1		1	Electroshock - SAMUS	5min	-33.635710	24.246070	10	80	0	10	TSPA	1
26-Oct	Baviaans	Gamtoos	1	Gordon O'Brien	1	Fyke Net (x1 medium)	2hrs	-33.760820	24.693240	70	30	0	0	GAES	1200
26-Oct	Baviaans	Gamtoos	1	Gordon O'Brien	1	Fyke Net (x1 medium)	2hrs	-33.760820	24.693240	70	30	0	0	GCAL	4
26-Oct	Baviaans	Gamtoos	1	Gordon O'Brien	1	Fyke Net (x1 medium)	2hrs	-33.760820	24.693240	70	30	0	0	BPAL	4
26-Oct	Baviaans	Gamtoos	1	Gordon O'Brien	2	Electroshock - SAMUS	15min	-33.760820	24.693240	20	40	10	30		0
29-Oct	Baviaans	Kouga River	3	Gordon O'Brien	1	Electroshock - SAMUS	5min	-33.859500	24.228800	20	80	0	0	BPAL	3
29-Oct	Baviaans	Kouga River	3	Gordon O'Brien	1	Electroshock - SAMUS	5min	-33.859500	24.228800	20	80	0	0	CGAR	3
29-Oct	Baviaans	Kouga River	3	Gordon O'Brien	1	Electroshock - SAMUS	5min	-33.859500	24.228800	20	80	0	0	MSAL	1
25-Oct	Baviaans	Tributary of Kouga Dam	1	Gordon O'Brien	1	Electroshock - SAMUS	5min	-33.652730	24.418860	20	80	0	0	PAFE	18
25-Oct	Baviaans	Tributary of Kouga Dam	1	Gordon O'Brien	1	Electroshock - SAMUS	5min	-33.652730	24.418860	20	80	0	0	BPAL	2
25-Oct	Baviaans	Tributary of Kouga Dam	1	Gordon O'Brien	1	Electroshock - SAMUS	5min	-33.652730	24.418860	20	80	0	0	SCAP	2
25-Oct	Baviaans	Bokkraal River	1	Gordon O'Brien	1	Electroshock - SAMUS	5min	-33.645980	24.445300	20	80	0	0	PAFE	100
25-Oct	Baviaans	Bokkraal River	1	Gordon O'Brien	1	Electroshock - SAMUS	5min	-33.645980	24.445300	20	80	0	0	SCAP	3
26-Oct	Baviaans	Groot River	1	Gordon O'Brien	1	Electroshock - SAMUS	5min	-33.695290	24.611700	0	60	0	40	AMOS	4
27-Oct	Baviaans	Groot River	2	Gordon O'Brien	2	Electroshock - SAMUS	5min	-33.695290	24.611700	0	60	0	40	BPAL	7
20-Oct	Baviaans	Groot River	1	Gordon O'Brien	2	Electroshock - SAMUS	15min	-33.695290	24.611700	20	40	0	40	BPAL	10