PART 3.2

Freshwater Biodiversity and Ecology

CONTENTS

PART 3. SCIENTIFIC ASSESSMENT OF AQUACULTURE DEVELOPMENT ZONES

Section 3.2 Freshwater Biodiversity and Ecology

Freshwater aquaculture is a fast-growing industry internationally, with the potential to contribute significantly to food security and economic development in many areas. Water is the primary requirement for aquaculture and the quality and quantity of the available water source determines which species and production systems are suitable and can be considered for development in a particular location. There has also been a growing concern around the past and potential future impacts of aquaculture on aquatic ecosystems, which have triggered numerous studies and calls for tighter controls on the aquaculture sector, including the development of guidelines for farming certain species and to address the potential negative impacts of aquaculture.

Freshwater aquaculture has been established as an industry in South Africa for several decades, with production of Rainbow trout (*Oncorhynchus mykiss*) being the oldest and best-established aquaculture activity, with commercial production commencing in the 1960s after nearly a century of trout rearing to support recreational trout fisheries. Other freshwater species commonly farmed throughout the country include Sharptooth (African) catfish (*Clarias gariepinus*), Tilapia (*Oreochromis mossambicus, Oreochromis niloticus and Tilapia rendalli*), Brown trout (*Salmo trutta*) and various ornamental fish species. Marron crayfish (*Cherax tenuimanus*) is currently the only freshwater crustacean species being cultured mainly in the Eastern Cape Province.

Human activities have had a series of profound effects on the background water quality in South Africa's rivers, dams, wetlands and reservoirs, as well as adverse impacts on several groundwater systems. In many areas, several different sets of activities have combined to exert complex changes in water quality resulting in the water quality of many areas of the country being compromised to the extent that it poses serious risks to human health and to the natural environment.

3.2.1 Environmental Attributes

Ecological sensitivity (or fragility) refers to the ecosystem's ability to resist disturbance and its capacity to recover from disturbance once it has occurred (resilience) with both abiotic and biotic components being taken into consideration in the assessment of ecological importance and sensitivity.

Environmental attributes that were considered in this assessment include the National Freshwater Ecosystem Priority Areas (NFEPAs) which relates to, at a national level, rivers, wetlands, catchments, fish species and distributions, fish species of conservation concern and fish sanctuaries, and other relevant aquatic biodiversity data including Present Ecological State (river condition), Ecological Importance and Ecological Sensitivity data. Additional and supplementary fish species information was obtained from the International Union for the Conservation of Nature (IUCN), South African National Biodiversity Institute (SANBI) and Succulent Karoo Ecosystem Plan (SKEP), as well as through consultation with provincial conservation agencies such as the Mpumalanga Tourism and Parks Agency (MTPA). Furthermore, provincial aquatic Critical Biodiversity Areas (CBAs), Ecological Support Areas (ESAs) and the South African Protected Areas data was also considered in this assessment.

3.2.2 Sensitivity Mapping

Different freshwater ecosystem types may have different levels of sensitivity to impacts likely to be associated with freshwater aquaculture development, as will those located in different regions, and those in different conditions. Assignment of overarching sensitivity scores per study area was based on the highest sensitivity rating for any rated attribute i.e. using the maximum rule. Thus, for example, if a quaternary catchment was rated low sensitivity for some criteria, medium for others and high for one criterion, the rating of HIGH would be accorded that quaternary as a whole and reflected in the sensitivity maps.

A big challenge undertaking the sensitivity analyses was dealing with data that were mapped at different scales. The data have not all been mapped at the same scale – some was mapped at quaternary scale; some at sub-quaternary scale; some are linear and some (e.g. Protected Areas data) took no cognisance of catchments. Also, existing NFEPA data are generally provided at the level of sub-quaternary catchments, with main stem rivers mapped at a scale of 1:500 000. The dataset is however far from perfect, and the mapping and rating of wetland presence, extent and condition in particular is problematic in many areas. The data also considerably under-represent other watercourse types, such as the ephemeral water courses and their alluvial flood plains in specifically drier areas of the country (e.g. Northern Cape and parts of the Free State). The accuracy of NFEPA data with regard to fish species distributions and river condition was also questioned.

Sensitivity rating types (i.e. biodiversity, water quality, hydrology and habitat quality) have provided guidance as to where to focus appropriate mitigation in order to reduce risk ratings in different sensitivity areas. The derivation of rating scores resulted in ratings of Low, Medium, High and Very High sensitivity (Table 3.2-1). The following notes apply to specific rated categories:

- In general, aquatic ecosystems categorised as CBAs were rated as Very High sensitivity and ESAs as Medium sensitivity, taking cognisance of management objectives for these categories;
- NFEPA data were rated considering the biodiversity implications of impacts to important fish populations, and both the number of affected threatened species and their threat status were individually considered;
- Other biodiversity factors, including the proximity of important frog or bird habitats or Ramsar wetlands, were also included using NFEPA RANK data from the NFEPA wetlands layer;
- Where supplementary fish data were available (e.g. MTPA data), these were rated separately from NFEPA data, to prevent double counting and thus possible elevation of sub-quaternary catchment importance; and
- Terrestrial (i.e. non-marine) protected areas were all accorded a sensitivity rating of Very High, compatible with their status as areas in which aquaculture is not promoted.

The sensitivity analysis have produced the following results in terms of the nine aquaculture development zones (ADZs) assessed in this study (Figure 3.2-1 to 3.2-9):

- Three ADZs comprise only High or Very High sensitivity areas (i.e. Richards Bay, Mpumalanga and Limpopo);
- Four ADZs comprise mainly High and Very High sensitivity areas, with limited Medium and Low sensitivity (i.e. Eastern Cape, Western Cape, Gauteng–North West and Free State–KwaZulu-Natal Highlands); and
- Two ADZs comprise mainly areas of Low sensitivity, with limited areas of Medium, High and Very High sensitivity (i.e. Vaalharts and Vanderkloof–Gariep).

Table 3.2-1: Selected ecological sensitivity indicators and associated sensitivity ratings used in this assessment

Dataset	Sensitivity Indicator	Environmental Attribute	Contribution to Sensitivity Rating Type	Sensitivity Rating
NFEPA (2012)	NFEPA Rivers	Flow (Perennial)	Water quality, hydrology, habitat quality	Medium
		Flow (Ephemeral)	Water quality, hydrology, habitat quality	High
		Free flowing rivers without flagship status	Hydrology	Low
		Free flowing rivers with flagship status	Hydrology	High
	River FEPAs [were not used for WC, KZN, EC]	FEPACODE (FEPA River)	Water quality, biodiversity, hydrology, habitat quality	Very High
		PHASE2FEPA (Phase 2 FEPA)	Water quality, biodiversity, hydrology, habitat quality	Medium
		UPSTREAM (Upstream management catchment)	Water quality, biodiversity	High
	FEPA Wetlands	RANK 1 & 2 (Wetlands within 500 m of an IUCN threatened frog, threatened water bird point locality / quaternary with Crane sightings / breeding areas / intact wetlands)	Water quality, biodiversity, habitat quality	Very High
		RANK 3 & 4 (Wetlands in sub-quaternaries with wetlands of (unstated) biodiversity importance; Wetlands in Category A, B or C condition associated with 3 or more wetlands)	Water quality, biodiversity, habitat quality	High
		RANK 5 & 6 (Wetlands in sub-quaternary with Working for Wetland wetlands; other wetlands excluding dams)	Water quality, biodiversity, habitat quality	Medium
		WETFEPA (Final selected wetland FEPAs)	Water quality, biodiversity, hydrology, habitat quality	High
	Fish Sanctuaries	FISHSANC (Fish sanctuary areas identified for threatened fish species)	Biodiversity	Very High
		FISHREHAB (Sub-quaternaries identified as necessary for rehabilitation for threatened fish species)	Biodiversity	High
		FISHFEPA (Fish sanctuary, translocation, relocation zones in AB condition for threatened fish species)	Biodiversity	Very High
		FISHFSA (Fish sanctuary, translocation, relocation zones NOT in AB condition for threatened fish species)	Biodiversity	High
	Fish Sanctuaries All Species	NOFISSANC (Number of threatened and near-threatened fish species in sub-quaternary = 0)	Biodiversity	Low
		NOFISSANC (Number of threatened and near-threatened fish species in sub-quaternary = 1-2)	Biodiversity	High
		NOFISSANC (Number of threatened and near-threatened fish species in sub-quaternary = >2)	Biodiversity	Very High
		STATUS (At least 1 vulnerable or near-threatened fish species known in sub-quaternary)	Biodiversity	High
		STATUS (At least 1 endangered or critically endangered fish species in sub-quaternary)	Biodiversity	Very High
SANBI/IUCN fish data (2018)	SANBI Supplementary Fish Species: Threatened taxa	BINOMIAL Species Name (Number of threatened species = 0)	Biodiversity	Low
		BINOMIAL Species Name (Number of threatened species = 1-2)	Biodiversity	High
		BINOMIAL Species Name (Number of threatened species = >2)	Biodiversity	Very High
MPTA (2017)	MPTA Supplementary Data / Fish Species of Concern	MTPA CONC (Areas where there are concerns with regard to aquaculture but no critical flaws and restricted or controlled aquaculture could occur)	Biodiversity	Medium
		MTPA CONC (areas where no aquaculture should occur on account of species of conservation concern and biodiversity sector plan)	Biodiversity	Very High
SKEP (2011)	SKEP Supplementary Data / Fish Species of Concern	NO_ENDEME (Number of endemics in a mapped polygon = ≥1)	Biodiversity, habitat quality	Very High
		BIODIVERSITY (Polygon is a local centre for aquatic endemism)	Biodiversity, habitat quality	Very High
ECape Fish – MARXAN (2017)	Eastern Cape Supplementary Data / Excel spreadsheet with sites and SQHASH links	OCCUR CODES (Was recorded but probably absent now; include if target can't be met elsewhere)	Biodiversity	Low
		OCCUR CODES (Present; Low confidence; Achieve target here THIRD)	Biodiversity	Medium
		OCCUR CODES (Present; Moderate confidence; Achieve target here SECOND)	Biodiversity	High
		OCCUR CODES (Present; High confidence; Achieve target here FIRST)	Biodiversity	Very High
DWS (2014) desktop PESEIS	PESEIES (Present Ecological State; Ecological Importance; Ecological Sensitivity)	Present Ecological State Category E & F	Water quality, biodiversity, hydrology, habitat quality	Medium
		Present Ecological State Category C & D	Water quality, biodiversity, hydrology, habitat quality	High
		Present Ecological State Category A & B	Water quality, biodiversity, hydrology, habitat quality	Very High

		Mean Ecological Importance Class (Low)	Water quality, biodiversity, hydrology, habitat quality	Low
		Mean Ecological Importance Class (Moderate)	Water quality, biodiversity, hydrology, habitat quality	Medium
		Mean Ecological Importance Class (High)	Water quality, biodiversity, hydrology, habitat quality	High
		Mean Ecological Importance Class (Very High)	Water quality, biodiversity, hydrology, habitat quality	Very High
		Mean Ecological Sensitivity Class (Low)	Water quality, biodiversity, hydrology, habitat quality	Low
		Mean Ecological Sensitivity Class (Moderate)	Water quality, biodiversity, hydrology, habitat quality	Medium
		Mean Ecological Sensitivity Class (High)	Water quality, biodiversity, hydrology, habitat quality	High
		Mean Ecological Sensitivity Class (Very High)	Water quality, biodiversity, hydrology, habitat quality	Very High
WESTERN CAPE CBA (2017)	Critical Biodiversity Areas – Western Cape	Sub-Category 2 (Terrestrial Critical Biodiversity Area)	Water quality, biodiversity, hydrology, habitat quality	Medium
		Sub-Category 2 (River Critical Biodiversity Area)	Water quality, biodiversity, hydrology, habitat quality	Very High
		Sub-Category 2 (Wetland Critical Biodiversity Area)	Water quality, biodiversity, hydrology, habitat quality	Very High
	Ecological Support Areas – Western Cape	Sub-Category 1 (Aquatic Ecological Support Area)	Water quality, biodiversity, hydrology, habitat quality	Medium
		Sub-Category 1 (Terrestrial Ecological Support Area)	Water quality, biodiversity, hydrology, habitat quality	Medium
KZN (2016)	KwaZulu-Natal CBA_Optimal_wll_03032016	LEGEND (Ecological Support Area)	Biodiversity, habitat quality	Medium
	KwaZulu-Natal ESA_wll_01022016	OPTIMAL (Critical Biodiversity Area)	Biodiversity, habitat quality	High
GDARD (2014)	Gauteng: C-Plan v33 1110ge	BDF DESC and CATEGORY (Prior Quaternary Catchment Pan cluster & CATEGORY = ESA)	Water quality, biodiversity, hydrology, habitat quality	Medium
		BDF DESC and CATEGORY (Prior Quaternary Catchment Pan cluster & CATEGORY = CBA)	Water quality, biodiversity, hydrology, habitat quality	Very High
EASTERN CAPE: AA_CBA_MAP_DRAFT 2 (2017)	W_CBA1_EC_FreshwaterMARXAN_River_BUFFER1km_v1	W_CBA1 = 3 (Ecological Support Area 1)	Biodiversity, habitat quality	Medium
	W_CBA1_EC_FreshwaterMARXAN_Rivers_20170619_v1	F_CBA1 = 2 & 3 (Ecological Support Area 2 and Critical Biodiversity Area 2, respectively)	Biodiversity, habitat quality	Medium
		F_CBA1 = 4	Biodiversity, habitat quality	High
		F_CBA1 = 5 (Critical Biodiversity Area 1)	Biodiversity, habitat quality	Very High
	W_CBA4_StrategicWaterAreas_v1	F_CBA4 = 2 & 3 (Ecological Support Areas)	Water quality, hydrology	Medium
	W_CBA7_EC_Integrated Wetlands_v1	F_CBA7 = 3	Biodiversity, habitat quality	Medium
		F_CBA7 = 4	Biodiversity, habitat quality	Very High
	lc_int2014 Image file	LC5_CLASS (Natural)	Water quality, biodiversity, hydrology, habitat quality	High
SAPAD (2017)	South African Protected Areas	MAJOR TYPE (Protected Environment)	Water quality, biodiversity, hydrology, habitat quality	Very High

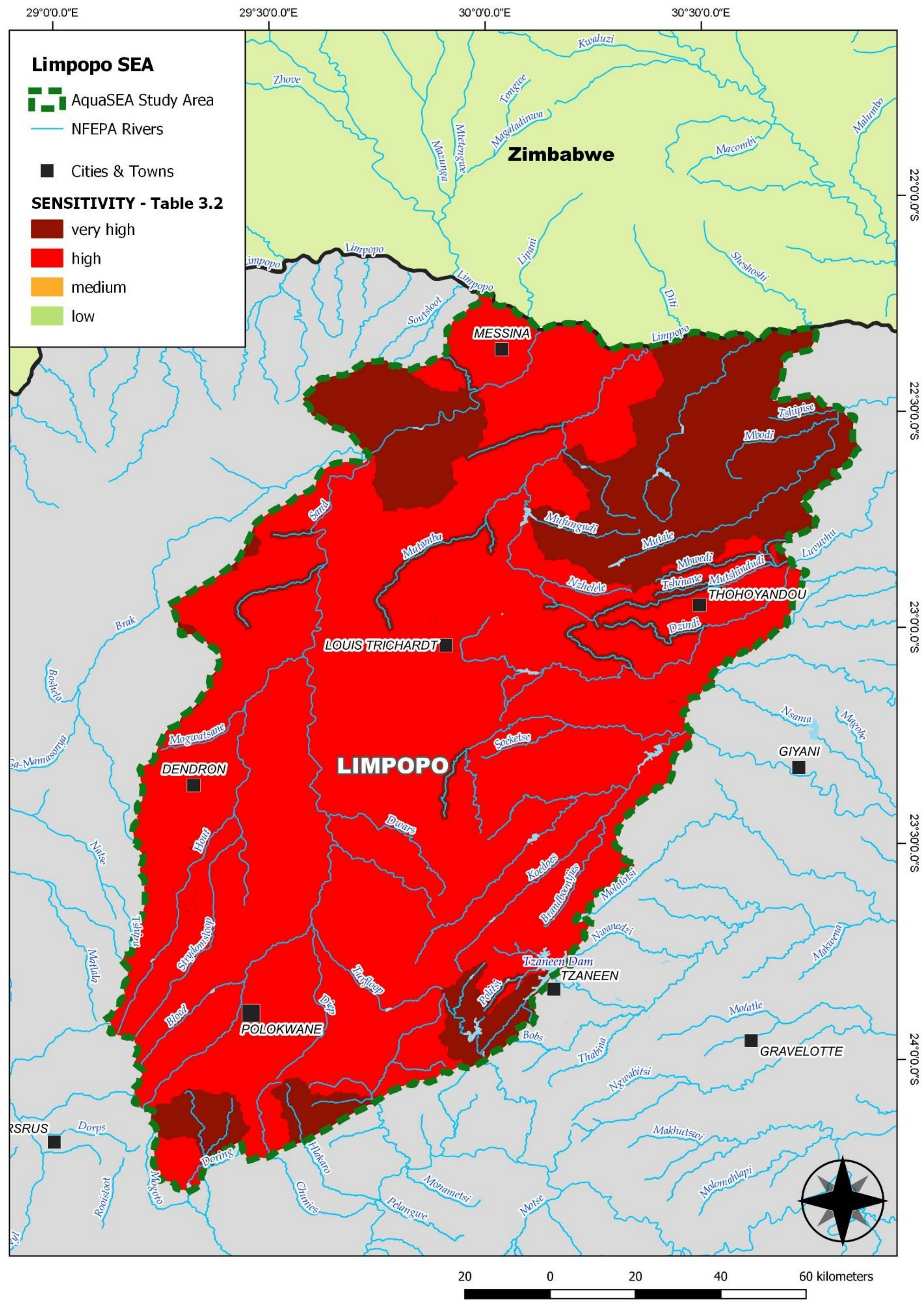

Figure 3.2-1: Ecological sensitivity of the Limpopo Study Area

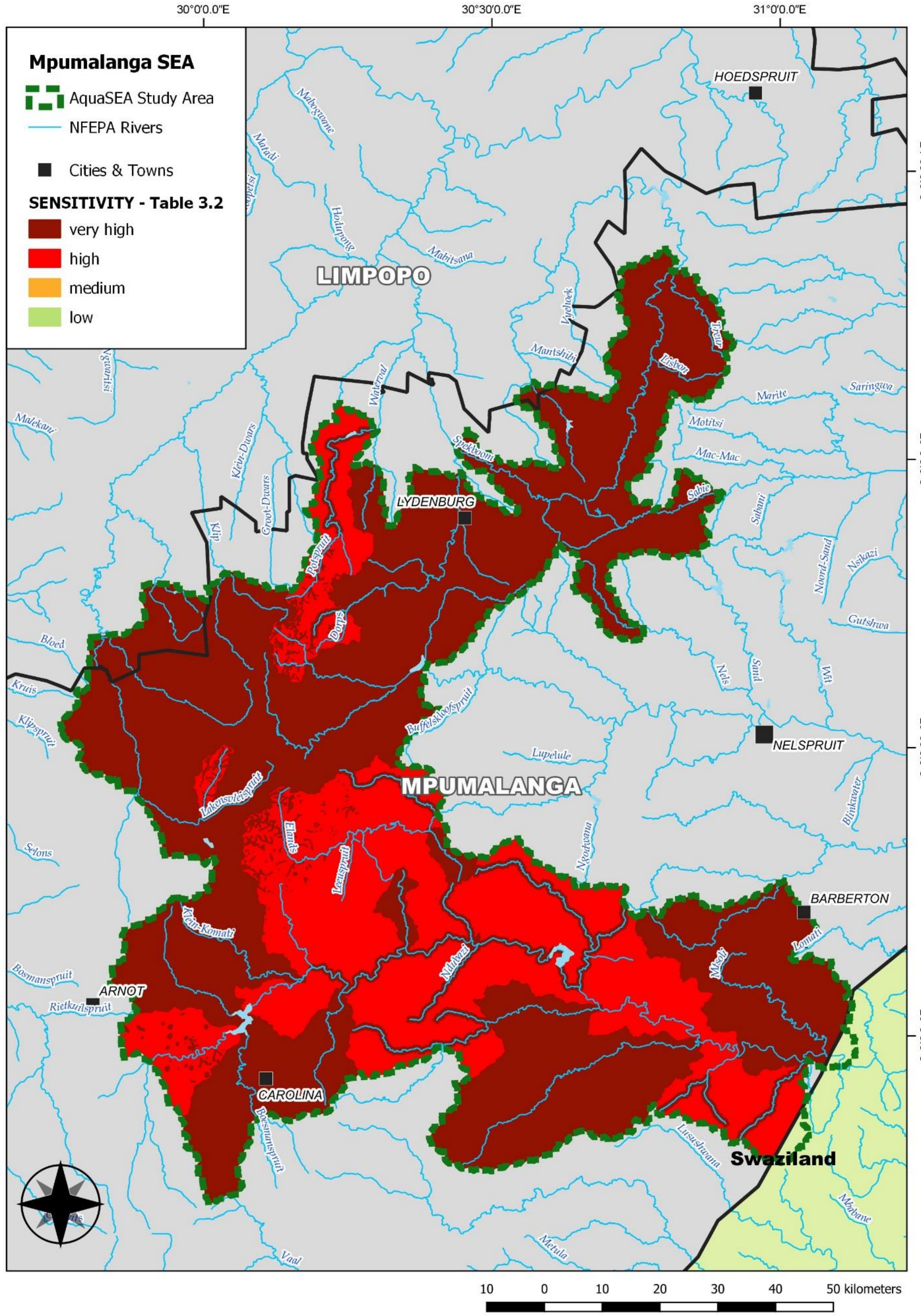

Figure 3.2-2: Ecological sensitivity of the Mpumalanga Study Area

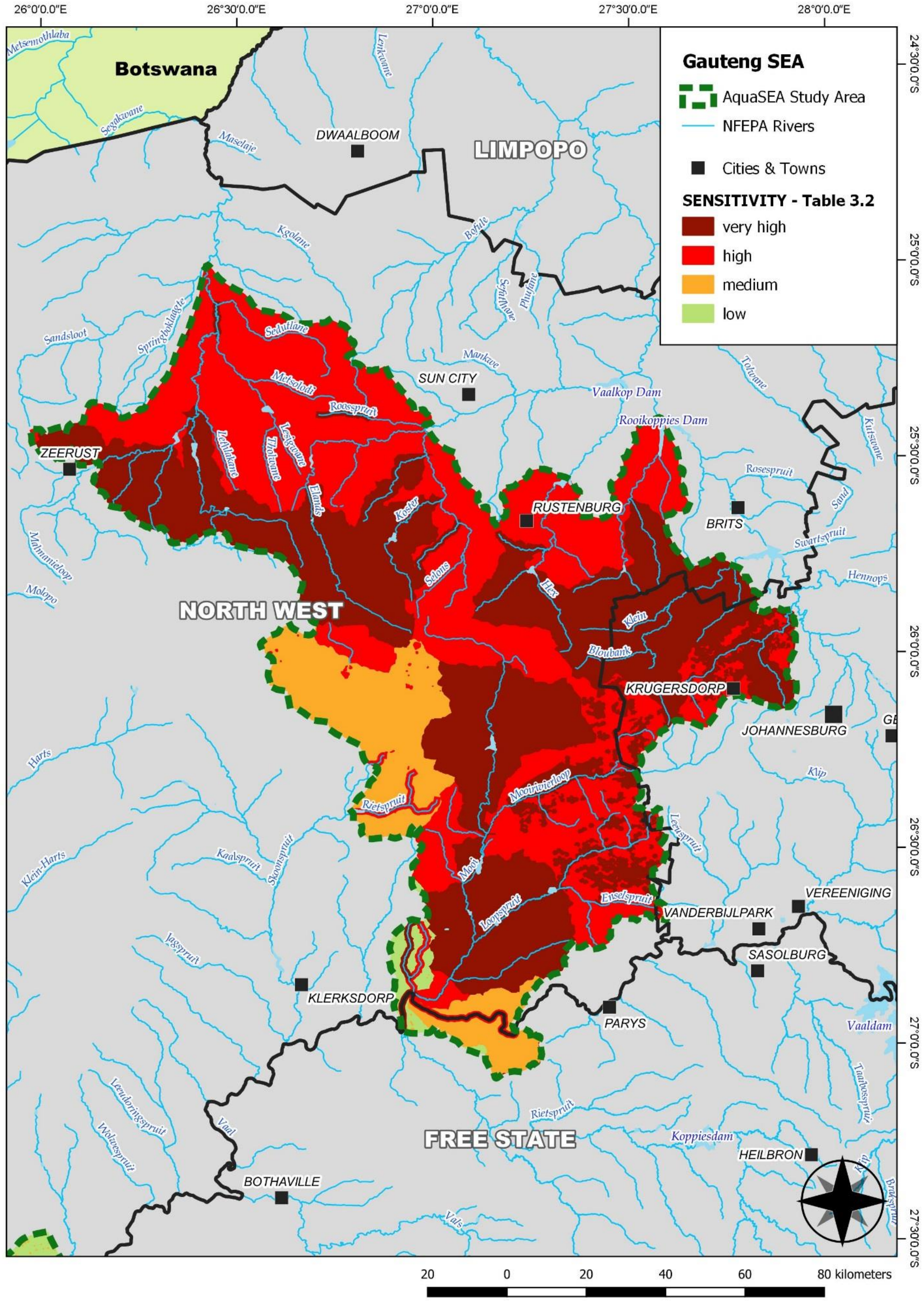

Figure 3.2-3: Ecological sensitivity of the Gauteng – North West Study Area

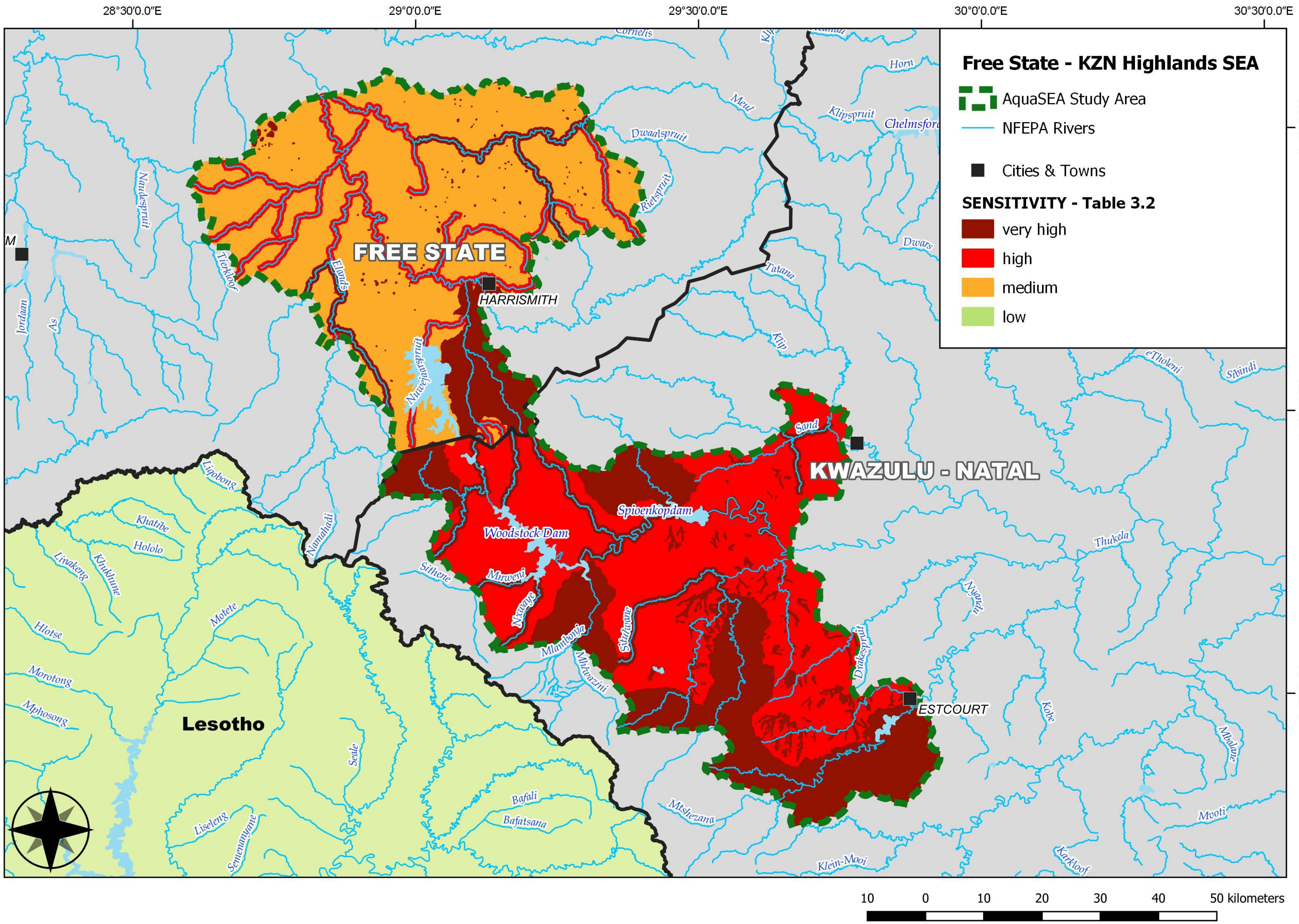

Figure 3.2-4: Ecological sensitivity of the Free State – KwaZulu-Natal Highlands Study Area

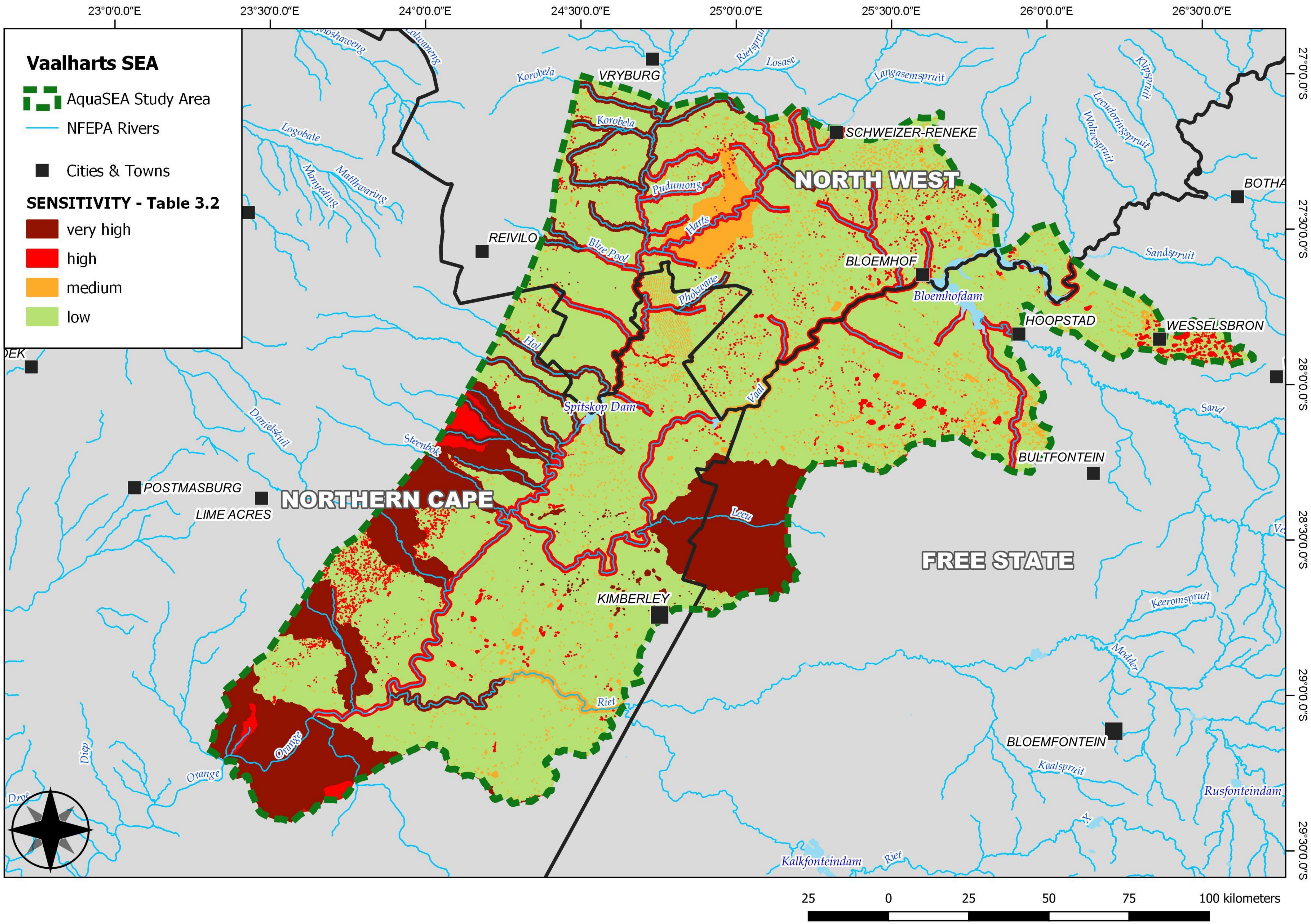

Figure 3.2-5: Ecological sensitivity of the Vaalharts Study Area

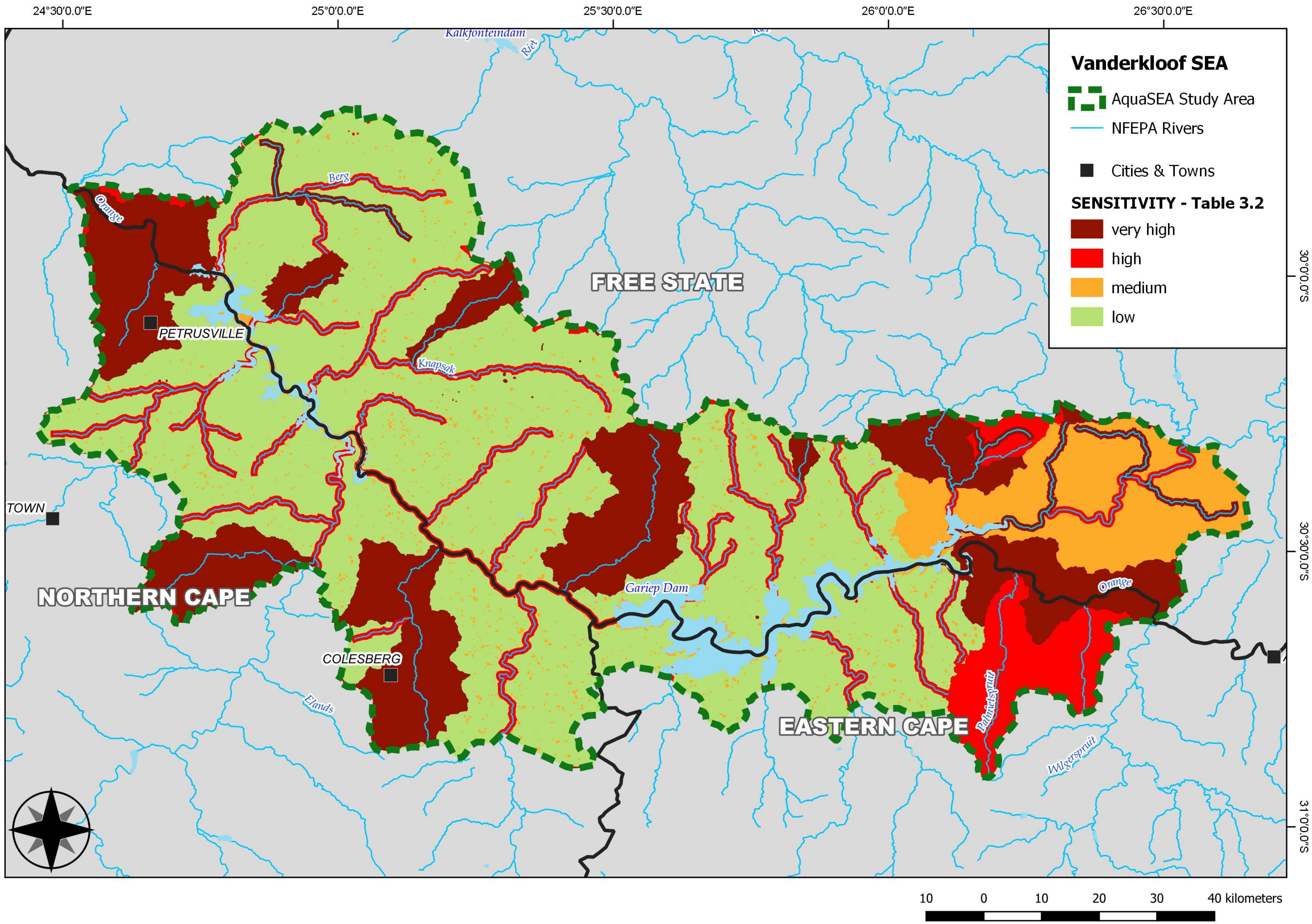

Figure 3.2-6: Ecological sensitivity of the Vanderkloof – Gariep Study Area

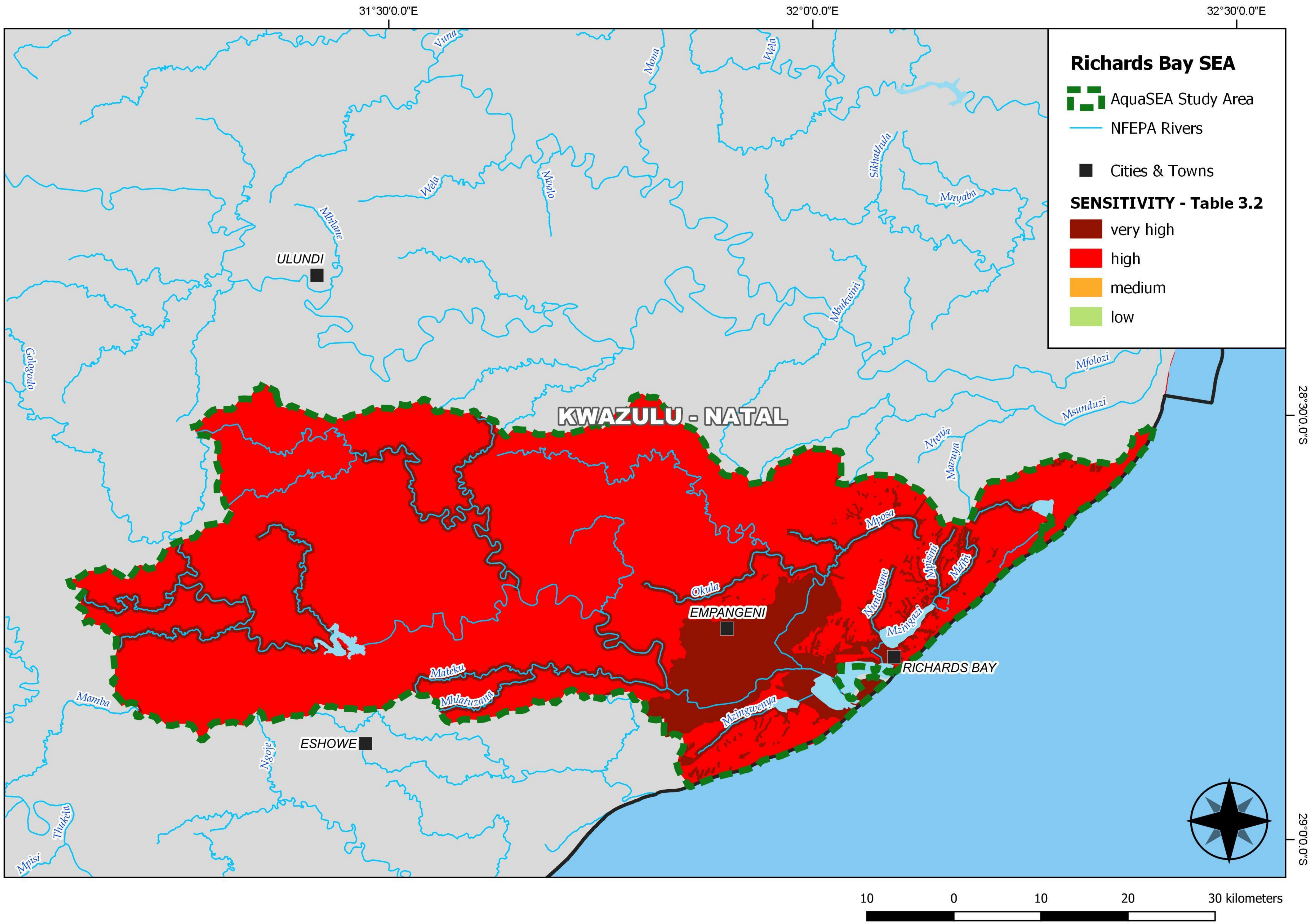

Figure 3.2-7: Ecological sensitivity of the Richards Bay Study Area

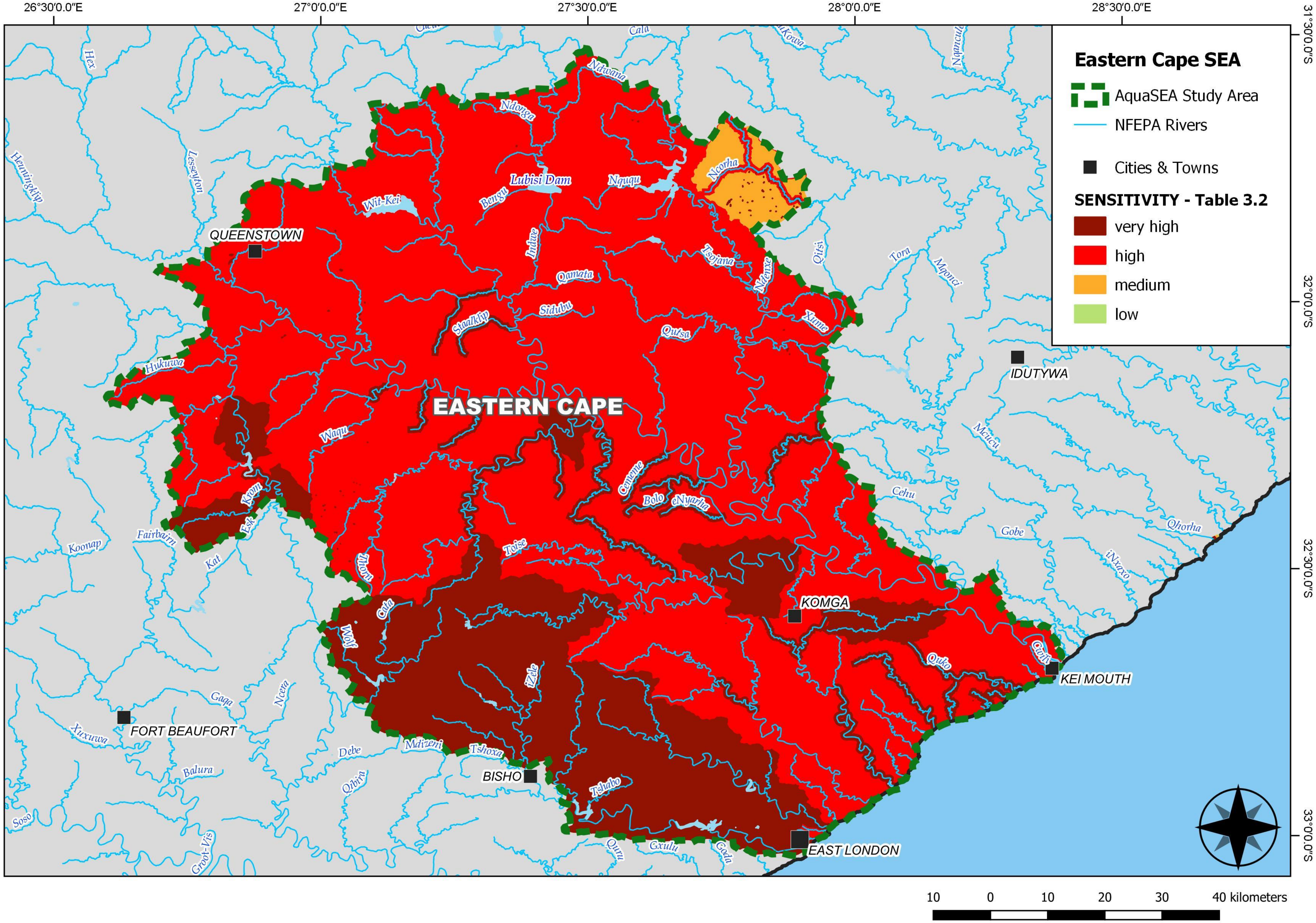

Figure 3.2-8: Ecological sensitivity of the Eastern Cape Study Area

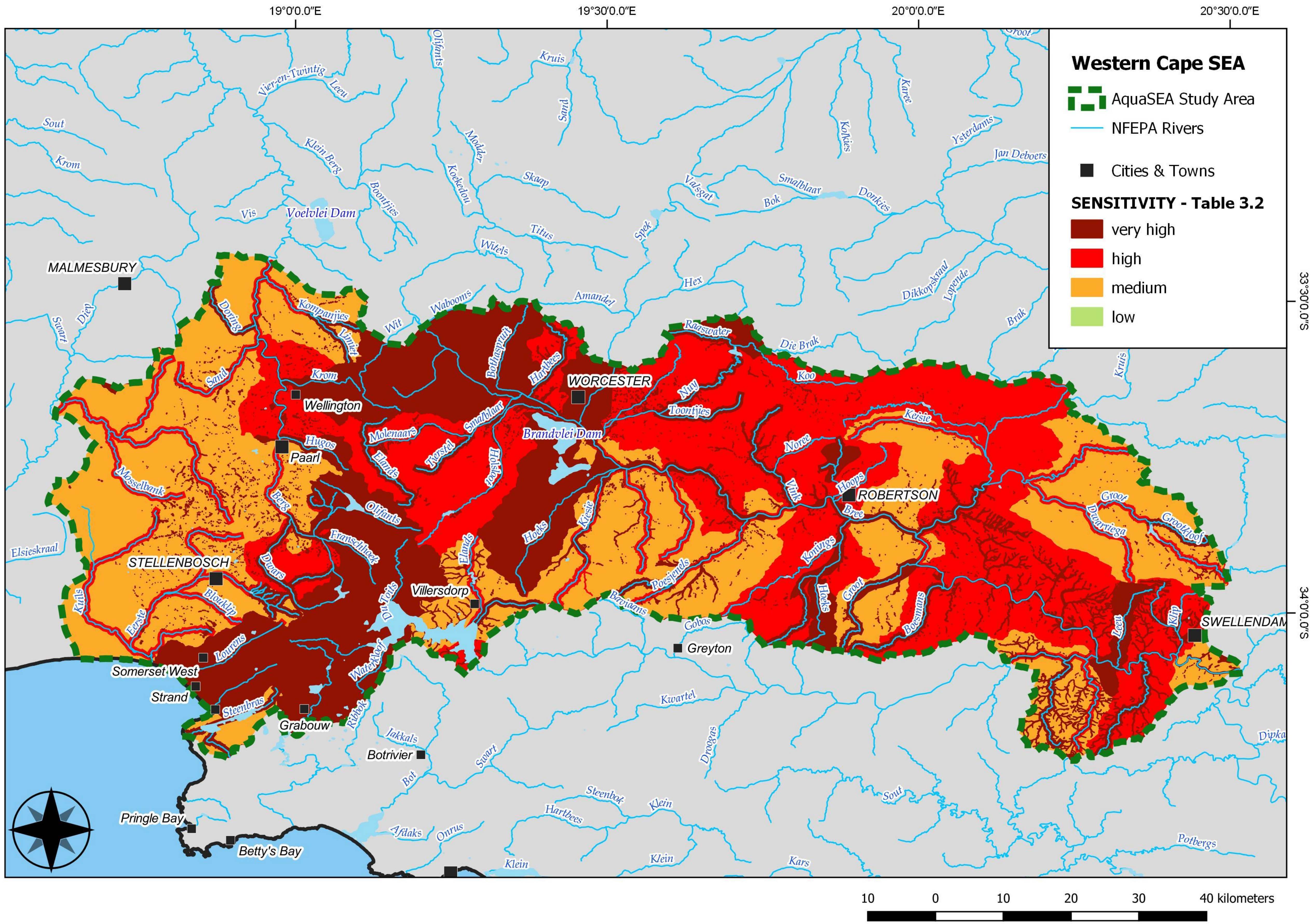

Figure 3.2-9: Ecological sensitivity of the Western Cape Study Area

3.2.3 Key Potential Impacts

A wide range of biodiversity and ecological impacts associated with different types of freshwater species and aquaculture production systems could potentially affect aquatic ecosystems and freshwater biota.

Resource quality issues of concern, as a result of freshwater aquaculture practices, include land use modifications, change in hydrological patterns, excessive use of freshwater, water pollution, nutrient load, chemical contamination (i.e. antibiotics, anti-foulants and pesticides), habitat modification and destruction, diseases and parasites, as well as negative impacts on indigenous aquatic and terrestrial biodiversity. The magnitude of these changes and impacts are usually catchment- or site-specific and are largely determined by the farm location, the type and intensity of the aquaculture production system, and its operational management regime.

Concerns around the ecological impacts of freshwater aquaculture systems include biodiversity impacts and losses associated with the accidental or intentional release of alien species into native systems, and the potential changes in water resource quality as a result of introductions. The ecological impacts of invasive and alien species span all levels of biological organization from genetic level to ecosystem level impacts, and may involve cumulative ecosystem-wide effects.

Freshwater ecosystems (rivers and wetlands) of the nine identified strategic focus areas were assessed in terms of its sensitivity to the following key impacts specifically associated with aquaculture:

- Water quality changes (including turbidity, nutrient enrichment and associated changes in dissolved oxygen availability).
- Biodiversity changes as a result of:
  - Changes in the genetic structure of wild populations of indigenous fish species that may result from alien fish being introduced into the ecosystem from aquaculture;
  - Invasion by alien aquaculture species with the resulting displacement of indigenous species; and
  - Invasion by alien or indigenous parasites or diseases associated with the aquaculture species.
- Hydrological changes.
- Modifications in habitat quality as a result of any of the above changes (e.g. increased sediment, changes in water flows and nutrients, aquatic plant or animal community structure), as well as changes that affect bank and bed stability and morphology (e.g. as a result of in- or near-channel construction).

3.2.4 Risk Assessment[1]

The greatest risk of **destruction of instream <u>biophysical</u> habitat** (specifically water quality and hydrology) are likely to be driven by **large-scale development of "open" aquaculture systems** – i.e. **dam cage culture, pond culture and flow-through/raceway systems** (Figure 3.2-10).

[1] The green dots indicate risk after mitigation, but does not imply that risk has been mitigated to acceptable levels. The position of the green dot indicates the risk class after mitigation, which may be high, even with mitigation.

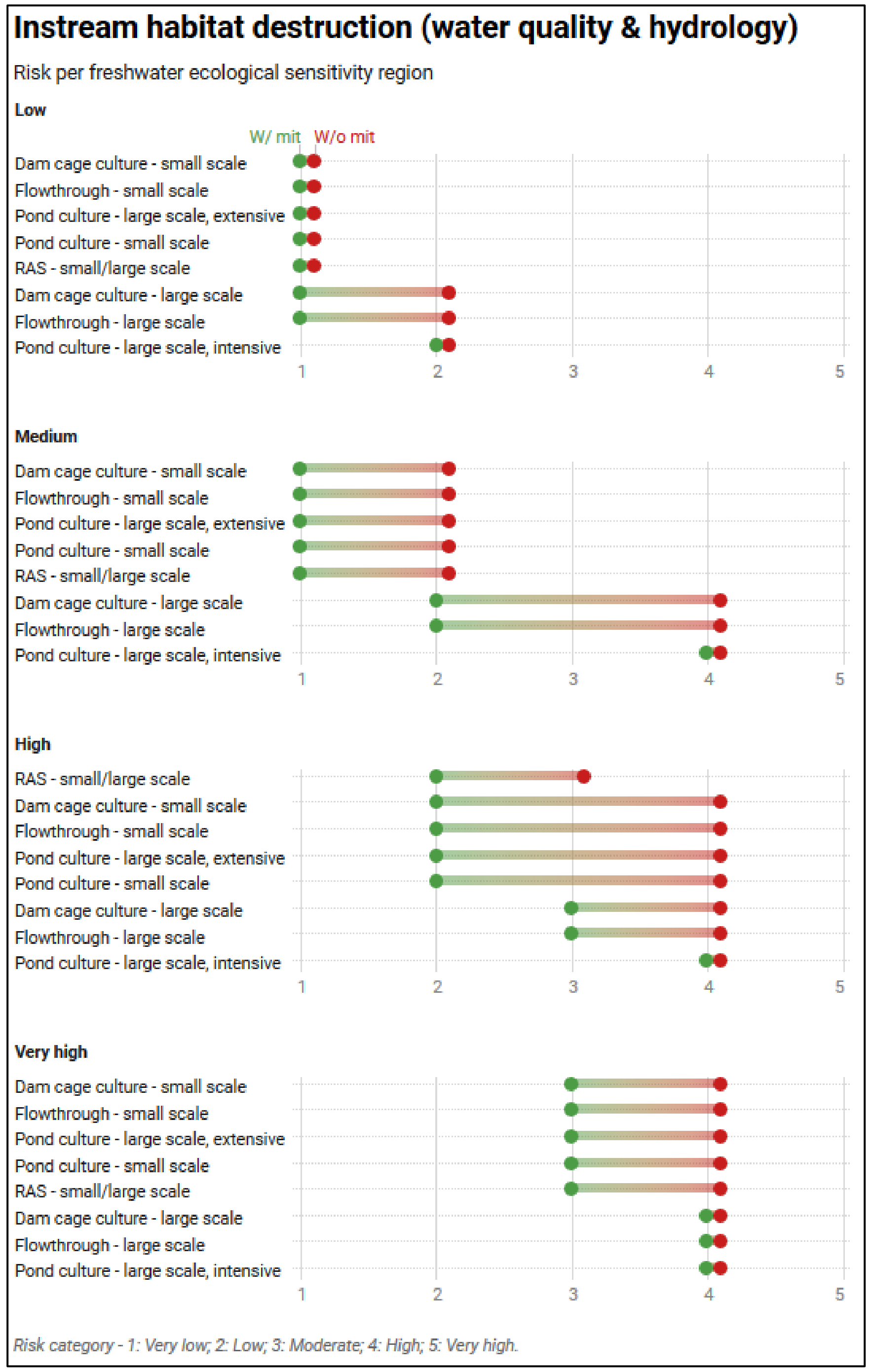

Figure 3.2-10: Risk summary for different freshwater aquaculture production systems – excluding biodiversity impacts associated with escapees. Risks are presented per ecological sensitivity region, without mitigation ("W/o mit") and with best practice management and mitigation ("W/ mit").

The impact of water quality and hydrological habitat destruction appears to be effectively mitigatable with best practice, but may not be acceptable in the most sensitive freshwater ecological regions.

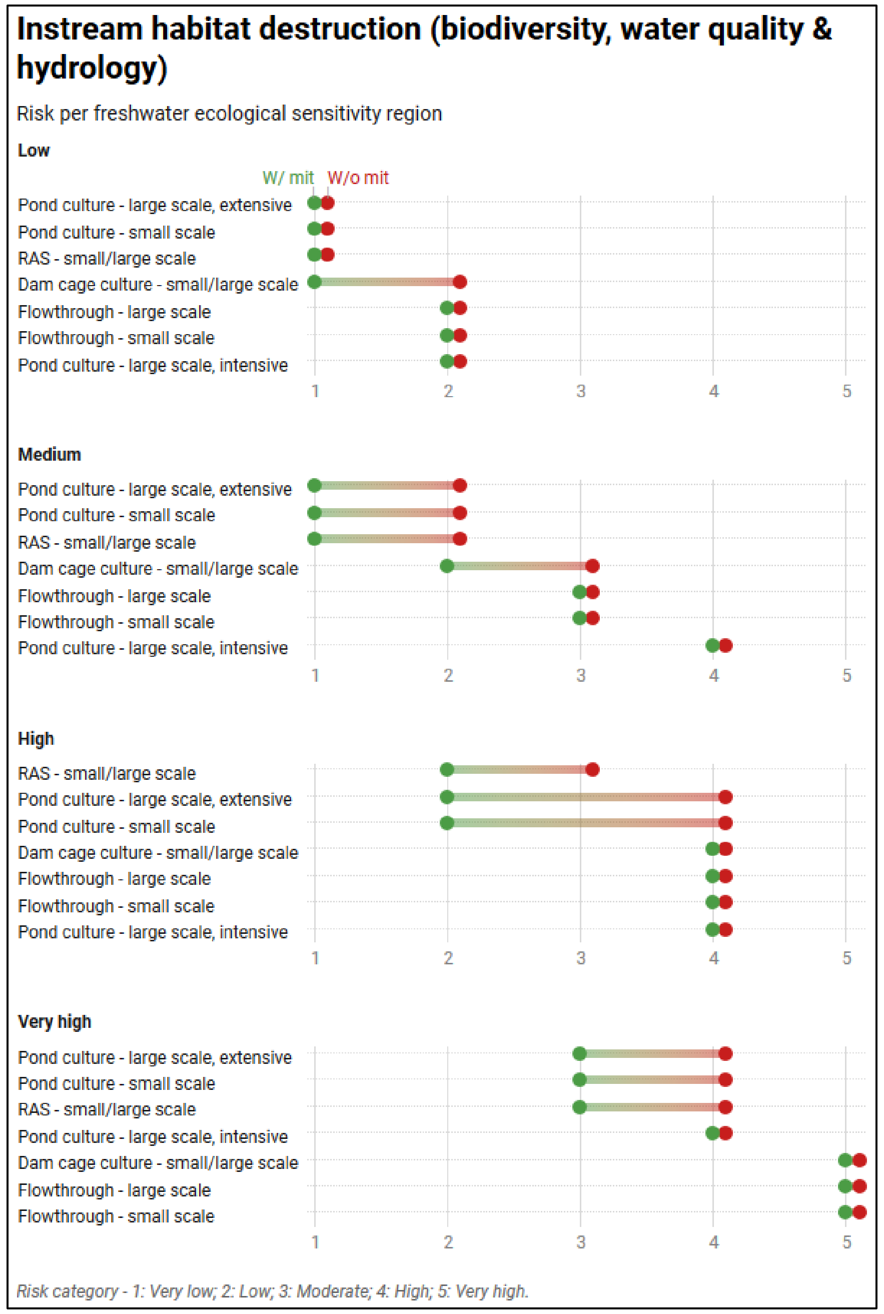

Figure 3.2-11: Risk summary for different freshwater aquaculture production systems – including biodiversity impacts associated with escapees. Risks are presented per ecological sensitivity region, without mitigation ("W/o mit") and with best practice management and mitigation ("W/ mit").

The **larger scale "open" aquaculture production systems similarly pose greater risk in terms of *biological and biophysical* habitat destruction**, especially in high and very high freshwater ecological sensitivity regions (Figure 3.2-11). Smaller scale operations and "closed" RAS systems provides an opportunity to greatly mitigate this impact.

The risk of **biodiversity loss or change depends on the invasive capacity of the species farmed** (Figure 3.2-12). **Highly invasive species** - **Nile tilapia, marron crayfish and trout species** (excl. trout in the Free State-Van der Kloof ADZ) **pose high risk, after mitigation**, in the most sensitive freshwater ecological regions, and should preferably be farmed in "closed" RAS.

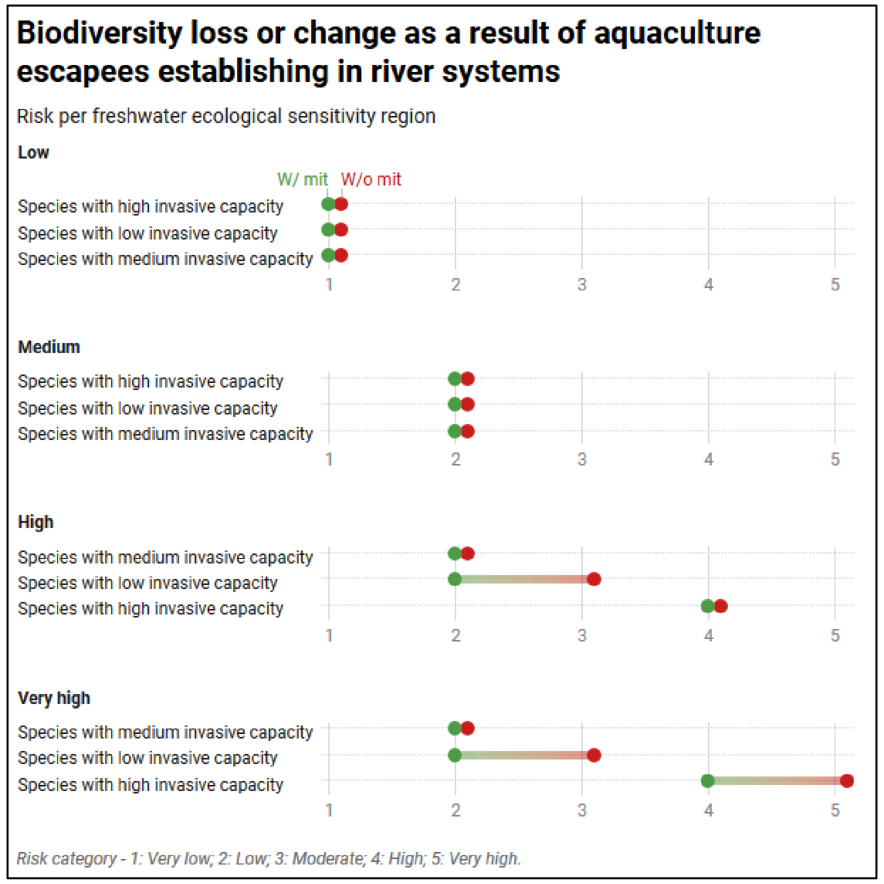

Figure 3.2-12: Risk summary for different freshwater aquaculture species – including biodiversity impacts associated with escapees. Risks are presented per ecological sensitivity region, without mitigation ("W/o mit") and with best practice management and mitigation ("W/ mit").

3.2.4.1 Proposed recommendations based on the outcome of the risk assessment

Based on the findings from the freshwater specialist assessment, assuming full mitigation measures are implemented and drawing on the resulting sensitivity mapping, the following recommendations are proposed for each freshwater focus area following the outcome of the risk assessment:

a. Limpopo

- African sharptooth catfish and Mozambique tilapia are locally occurring species likely to invade into catchments and thus would be suitable (in terms of the SEA) for open-water culture mainly in areas of confirmed Low and Medium sensitivity OR where the nearest watercourses to the operation already have this species naturally occurring, and only local stock is used, to prevent impacts on genetic stock; and
- In all cases, full mitigation and best practice measures would be required.

b. Mpumalanga

- Mozambique tilapia are likely to invade into catchments and thus would be suitable (in terms of the SEA) for open-water culture mainly in areas of confirmed Low and Medium sensitivity OR where the nearest watercourses to the operation already have this species naturally occurring, and only local stock is used, to prevent impacts on genetic stock;
- Nile tilapia and Rainbow and Brown trout pose a biodiversity threat in this area and are not locally indigenous. They are suitable (in terms of the SEA) for open-water culture mainly for areas of confirmed Low and Medium sensitivity. Rainbow and Brown trout culture should however be promoted in areas where trout presence has been verified; and
- In all cases, full mitigation and best practice measures would be required.

c. Gauteng – North West

- African sharptooth catfish and Mozambique tilapia are locally occurring species likely to invade into catchments and are suitable for open-water culture in areas of confirmed Low and Medium sensitivity OR where the nearest watercourses to the operation already have these species naturally occurring, and only local stock is used, to prevent impacts on genetic stock;
- Nile tilapia pose a biodiversity threat in this area and is suitable for open-water culture mainly in areas of confirmed Low or Medium sensitivity; and
- In all cases, full mitigation and best practice measures would be required.

d. Free State – Vaalharts

- African sharptooth catfish is a locally occurring species likely to invade into catchments and suitable (in terms of the SEA) for open-water culture in areas of confirmed Low and Medium sensitivity OR where the nearest watercourses to the operation already have this species naturally occurring, and only local stock only is used, to prevent impacts on genetic stock; and
- In all cases, full mitigation and best practice measures would be required.

e. Free State – KwaZulu-Natal Highlands

- Rainbow and Brown trout pose a fairly high biodiversity threat in this area and are not locally indigenous. They are suitable (in terms of the SEA) for open-water culture mainly in areas of confirmed Low and Medium sensitivity with full mitigation and best practice measures implemented.

f. Free State – Vanderkloof-Gariep

- Rainbow and Brown trout pose a low biodiversity threat in this area and although not locally indigenous, they are unlikely to establish populations in the wild because of high water temperatures. They are suitable (in terms of the SEA) for open-water culture mainly in areas of confirmed Low and Medium sensitivity; and
- In all cases, full mitigation and best practice measures would be required.

g. Richards Bay

- African sharptooth catfish and Mozambique tilapia are locally occurring species likely to invade into catchments and are suitable (in terms of the SEA) for open-water culture in areas of confirmed Low and Medium sensitivity OR where the nearest watercourses to the operation already have this species naturally occurring, and only local stock is used, to prevent impacts on genetic stock;
- Nile tilapia pose a high biodiversity threat in this area and are not locally indigenous. They are suitable (in terms of the SEA) for open-water culture mainly in areas of confirmed Low sensitivity, and should be used only with systems (e.g. RAS) that pose low risk of escapees; and
- In all cases, full mitigation and best practice measures would be required.

h. Eastern Cape

- Mozambique tilapia is a locally occurring species likely to invade into catchments and is suitable (in terms of the SEA) for open-water culture in areas of confirmed Low and Medium sensitivity;
- Nile tilapia and Brown and Rainbow trout pose a high biodiversity threat in this area and are not locally indigenous. They are suitable (in terms of the SEA) for open-water culture mainly in areas of confirmed Low sensitivity;
- Marron poses a high biodiversity threat in this area should they escape from aquaculture facilities. Therefore, open-water production is promoted only in areas of confirmed Low sensitivity. Given the biodiversity threats posed by this species, flow-through and dam cage culture production approaches, all associated with bio-security risk, would not be appropriate to their culture in terms of the SEA; and
- In all cases, full mitigation and best practice measures would be required.

i. Western Cape

- Brown and Rainbow trout pose a biodiversity threat in this area and are not locally indigenous. They are suitable (in terms of the SEA) for open-water culture mainly in areas of confirmed Low and Medium sensitivity, where any of the production systems could be used OR in verified existing trout presence areas. Where these are located in Medium or High sensitivity areas, only RAS is promoted – it is noted that in some verified trout presence areas (e.g. the Molenaars River system), trout pose high biodiversity threats to endemic fish species. Also, while RAS poses low escape risk there is still a possibility of accidental or deliberate release of fish and ideally if trout are not present in a catchment and the catchment is ecologically sensitive, then aquaculture should not be promoted in that catchment. The industry should rather aim to intensify their operations in areas that are already ecologically compromised by the presence of trout. In very sensitive catchments where trout are already present, further development should be promoted mainly in RAS.

NB: The above recommendations are relevant to sensitivities that have been confirmed at finer scales, and in-field. For example, an area identified that is classified as high sensitivity based on the available spatial data applied in this assessment may in reality be confirmed as low sensitivity on the ground, and *vice versa* based on site-specific verification.

3.2.4.2 Risk assessment implications for environmental assessment

<u>High and Very High risks after mitigation indicates key issues</u> specific to freshwater aquaculture that needs to be addressed in environmental assessment to indicate whether the risks may be reduced to acceptable levels.

Table 3.2-2: Risk assessment implications for environmental assessment

Species & production system	Key issue	Assessment implication
Dam cage culture	Destruction of instream *biophysical* habitat (specifically water quality and hydrology)	A water quality and quantity monitoring plan needs to be in place.
	Destruction of instream *biophysical* and *biological* habitat (biodiversity, water quality and hydrology)	An animal health and biosecurity monitoring and response plan needs to be in place.
Flow-through systems, including raceways	Destruction of instream *biophysical* habitat (specifically water quality and hydrology)	A water quality and quantity monitoring plan needs to be in place.
	Destruction of instream *biophysical* and *biological* habitat (biodiversity, water quality and hydrology)	An animal health and biosecurity monitoring and response plan needs to be in place.
Pond culture	Destruction of instream *biophysical* habitat (specifically water quality and hydrology)	A water quality and quantity monitoring plan needs to be in place.
	Destruction of instream *biophysical* and *biological* habitat (biodiversity, water quality and hydrology)	An animal health and biosecurity monitoring and response plan needs to be in place.
Species with high invasive capacity (Nile tilapia; marron crayfish; trout species (excl. trout in the Free State-van der Kloof ADZ).	Biodiversity loss / change resulting from aquaculture escapees establishing in water bodies	A biosecurity monitoring and response plan needs to be in place. Site-specific biodiversity risk and benefit assessment is required.

3.2.5 Management Actions and Best Practice Guidelines

Table 3.2-3: Minimum information requirements for the development of best management practices for freshwater aquaculture.

Planning phase

• General information: species to be farmed, total area in production, total annual production, value of production, size of the operation, employment opportunities, major milestones in terms of marketing and sales, future prospects, and climate information.
• Site-specific information for individual farms:
  ○ Location
  ○ Significant features, i.e. terrain, soils, elevation, vegetation, proximity to other aquaculture facilities, likelihood of pollution from other land and water users, delineate natural and modified habitats, identify unique and protected areas, presence of red data species and unique populations
  ○ Aquaculture system (cages, ponds, raceways, RAS, etc.)
  ○ Area in production (size)
  ○ Source of water
  ○ Culture species (sterile or single sex organisms recommended)
  ○ Annual production volumes
  ○ Source of power supply for aquaculture operation.

Construction phase

• Soil erosion and sedimentation:
  ○ Extent of earth excavation and moving activities
  ○ Slope where construction is taking place
  ○ Bank stabilization measures
  ○ Construction of structures (e.g. weirs) for diversion / embankment of water
  ○ Preventative measures for soil erosion and siltation.

Operational phase

• Production system:
  ○ Description of production system
  ○ Quality of source water
  ○ Water use rate
  ○ Water intake and distribution
  ○ Water release – frequency, volume, quality
  ○ Retention time
  ○ Condition of facilities – maintenance of facilities, erosion control, general tidiness.
• Production methodology:
  ○ Species
  ○ Source of seed and stocking density
  ○ Fertilizers and liming materials – types, amounts, application frequency
  ○ Feed – type and protein, P and N content
  ○ Feeding – frequency, amount per day, method of application, amount per crop
  ○ Mechanical aeration – type of aerators, amount of aeration per pond, operating schedule
  ○ Water exchange – method of application, amount per day, use in response to water quality emergencies, total water use
  ○ Species health management (including information on the use of antibiotics and hormones)
  ○ Water quality management (e.g., copper sulphate, zeolite, sodium chloride) —doses, frequencies, methods of application
  ○ Use of particular approaches (e.g., sand filters) to minimize pollution and transmission of fish ova to receiving streams
  ○ Monitoring frequency to facilitate early detection of disease and / or other red flags
  ○ Harvest data—harvest method and harvest statistics.
• Effluents:
  ○ Annual volume and frequency of discharge
  ○ Average quality and maximum concentrations of nutrients, suspended solids, biochemical oxygen demand, dissolved oxygen, pH
  ○ Annual loads of N, P, TSS, and 5-day BOD
  ○ Treatment of effluent before final discharge
  ○ Conditions around final discharge point
  ○ Receiving waters – area, volume, flushing rate, quality, other users, other pollution sources
  ○ Licence and permit conditions and monitoring.
• Miscellaneous:
  ○ Use of pesticides
  ○ Predator control method (e.g., nets to prevent piscivorous birds from eating stock)
  ○ Storage of materials e.g., feeds, fertilizers, liming materials, fuels
  ○ Waste disposal - mortalities, used oil, expired or unwanted chemicals, refuse, sewage
  ○ Observations of surrounding environment - evidence of eutrophication or sedimentation in receiving water body, damage caused by improper waste disposal, ecological nuisances

Rehabilitation and post closure
• Design and implement mitigation measures to achieve no net loss of biodiversity where feasible for post operation restoration of habitats.   ○ Offset of losses through the creation of ecologically comparable area(s) managed for biodiversity.

3.2.6 Monitoring Requirements

To ensure effective environmental management of aquaculture practices, a sound monitoring programme is required. Environmental and water resource monitoring programmes for freshwater aquaculture should be designed and implemented with the aim to address all activities that have been identified to have potentially significant impacts on the receiving environment and which should be aligned with Best Management Practices (BMPs). The frequency at which monitoring is conducted should be sufficient to provide representative data for the parameters being monitored. Monitoring should be conducted by suitably trained individuals using calibrated and maintained instruments. Data should be analyzed frequently and appropriately and compared with the necessary guidelines and standards so that any necessary corrective actions can be taken timeously. Proper record keeping of data and information is equally important. The type and frequency of monitoring required will be determined by applicable approvals, authorisations and licensing conditions.

Although the development of an appropriate, broad framework for all monitoring requirements in relation to aquaculture activities was hampered by the sheer variety of possible aquaculture activities, the different organisms intended for culture, the specific issues linked to the intended location of operations, and by the range of sizes and scales of aquaculture operations, at the strategic level of this assessment, it was possible to broadly specify the types of parameters that need to be considered in developing a monitoring programme for freshwater aquaculture operations. This means that the project-level details required for a monitoring programme should then be clearly defined during the site-specific assessment for a newly proposed aquaculture operation, taking into consideration the scale of the proposed operations, the characteristics of the intended development site(s), and the specific risks associated with the type(s) of organisms proposed for culture in the given location.

It is important to note that a sound environmental assessment of a particular project requires good (reliable) data. In order to ensure that good quality data are collected, standardised monitoring protocols and quality control as well as assurance procedures have to be followed both in the collection and analysis of the samples by trained personnel. This information should include sufficient background data on seasonal variations in water flows and water quality, the existing populations of aquatic biota, potential health threats posed to a proposed aquaculture operation by existing (upstream) water characteristics and uses, and information on other (downstream) water users and their sensitivities to specific water quality issues.

These data would then provide a clear planning framework for the proposed aquaculture operation during the planning, construction, operational and decommissioning phases of the project. In turn, it would allow the project proponent and local, provincial and national authorities to reach agreement as to precisely what parameters should be monitored, how often (frequently) monitoring should be carried out, and how (and by whom) the information will be used. Monitoring undertaken by the project proponent must be verified and audited by the relevant authority as required.

In those cases where a proposed aquaculture operation is considered to be small in area and isolated from other operations, it is likely that the impact of the operation would be localized and low. In contrast to such small operations, two possible scenarios could occur that might increase concerns about negative environmental impacts;

- The first scenario relates to large-scale commercial aquaculture farms which, because of their large size, could have a greater risk of negative impacts. Despite this, large-scale aquaculture operations have ready access to a range of technologies that could mitigate or eliminate these risks.
- The second scenario occurs when a number of small-scale aquaculture operations are concentrated in a relatively small geographical area. Individually, each aquaculture operation may have very little impact and pose low to very low environmental risks. However, should each of the individual aquaculture operations be successful and profitable, their cumulative impact could potentially pose greater environmental risks and possibly lead to greater negative impacts on the receiving ecosystem opposed to a single operation.

The typical sets of parameters that would need to be considered for inclusion in a monitoring programme that is designed for a specific aquaculture operation would include:

- Seasonal variations in water flow of the source water to be used in the operation;
- Seasonal variations in the water quality of the source water and the potential risks to human health, the environment and aquaculture product quality posed by particular water quality variables in the source water;
- Volumes of water taken into the aquaculture operation;
- Volumes of effluent (or through-flow water) discharged from the operation;
- The quality of the water discharged from the operation, and the degree to which the quality parameters comply with specific water use and effluent discharge license conditions;
- The efficacy of any water treatment process used to improve source water for use in the operation, or reduce high concentrations of specific water quality variables in the discharge water;
- The efficacy of all measures put in place to prevent the transfer of cultured organisms or their ova and offspring from the aquaculture operation to the natural environment;
- Water quality parameters within the aquaculture operation that have any positive or adverse impact on the viability and growth of the organisms being cultured; and
- The microbiological quality of the final product(s) produced by the aquaculture operation.

Where smaller operations have been aggregated or located close to one another, the monitoring programme could be adapted to consider the combined characteristics of the inflow water and effluent quality, as well as the quality of the product(s) produced by the grouped operations.