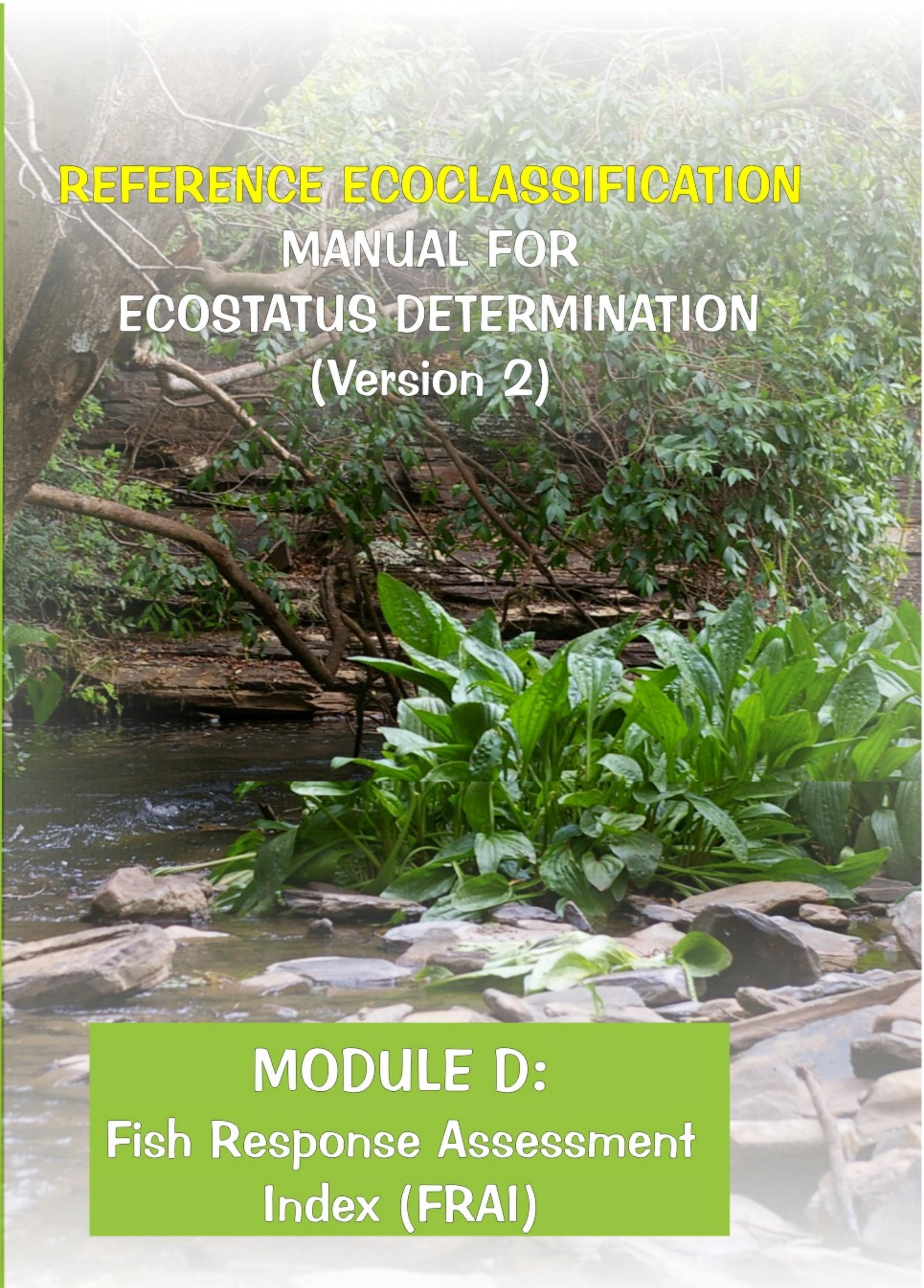
ECOCLASSIFICATION



REFERENCE ECOCLASSIFICATION MANUAL FOR ECOSTATUS DETERMINATION (Version 2)

MODULE D: Fish Response Assessment Index (FRAI)

water & forestry
Department:
Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

Water
Research
Commission

RIVER ECOCLASSIFICATION
MANUAL FOR ECOSTATUS DETERMINATION
(Version 2)

MODULE D: Fish Response Assessment Index (FRAI)

CJ KLEYNHANS
Department of Water Affairs & Forestry, Resource Quality Services, Pretoria

REPORT REFERENCE

Kleynhans CJ. , 2007. Module D: Fish Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No.

STRUCTURE OF THE MANUAL

The manual consists of the following modules:

- MODULE A: ECOCLASSIFICATION AND ECOSTATUS MODELS
- MODULE B: GEOMORPHOLOGICAL DRIVER ASSESSMENT INDEX (GAI)
- MODULE C: PHYSICO-CHEMICAL DRIVER ASSESSMENT INDEX (PAI)
- **MODULE D: FISH RESPONSE ASSESSMENT INDEX (FRAI)**
- MODULE E: MACRO-INVERTEBRATE RESPONSE ASSESSMENT INDEX (MIRAI)
- MODULE F: RIPARIAN VEGETATION RESPONSE ASSESSMENT INDEX (VEGRAI)
- MODULE G: INDEX OF HABITAT INTEGRAITY

This module is Module D and consists of the FRAI model explanation. The module provides the background to and scientific rationale for the FRAI.

PURPOSE OF THE MANUAL : MODULE D

Provides a step by step guideline to the appropriate specialists on how to use the FRAI.

WHO SHOULD APPLY THESE MODELS?

An experienced fish specialist.

NOTE: It is strongly recommended that the user participates in training courses and/or contact the authors of this manual when applying the models

The manual is structured in a main section which focuses on how to populate the models and appendices that provide the background, scientific rationale and the modelling approach.

ABBREVIATIONS

ASPT	Average Score Per Taxon
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EcoSpecs	Ecological Specifications
EIS	Ecological Importance and Sensitivity
ER	Ecological Reserve
EWR	Ecological Water Requirements
FAII	Fish Assemblage Integrity Index
FHS	Fish Habitat Segment
FRAI	Fish Response Assessment Index
GAI	Geomorphology Driver Assessment Index
HAI	Hydrology Driver Assessment Index
IHI	Index of Habitat Integrity
ISP	Internal Strategic Perspective
IFR	Instream Flow Requirements
MCDA	Multi-Criteria Decision Analysis
MIRAI	Macro Invertebrate Response Assessment Index
PAI	Physico-chemical Driver Assessment Index
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RERM	Rapid Ecological Reserve Methodology
RHP	River Health Programme
RU	Resource Unit
RVI	Riparian Vegetation Index
SASS	South African Scoring System
VEGRAI	Riparian Vegetation Response Assessment Index

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1 FISH RESPONSE ASSESSMENT INDEX (FRAI)

The guidelines presented here assume that the reader has some experience of fish ecology.

1.1 THE PRINCIPLES OF THE FRAI

1.1.1 Definition of the FRAI

- The FRAI is an assessment index based on the environmental intolerances and preferences of the reference fish assemblage and the response of the constituent species of the assemblage to particular groups of environmental determinants or drivers (Figure 1.1)
- These intolerance and preference attributes are gategorized into metric groups with constituent metrics that relates to the environmental requirements and preferences of individual species.
- Assessment of the response of the species metrics to changing invironmental conditions occur either through direct measurement (surveys) or are inferred from changing environmental conditions (habitat). Evaluation of the derived response of species metrics to habitat changes are based on knowledge of species ecological requirements. Usually the FRAI is based on a combination of fish sample data and fish habitat data.
- Changes in environmental conditions are related to fish stress and form the basis of ecological response interpretation (cf. **Appendix A**).

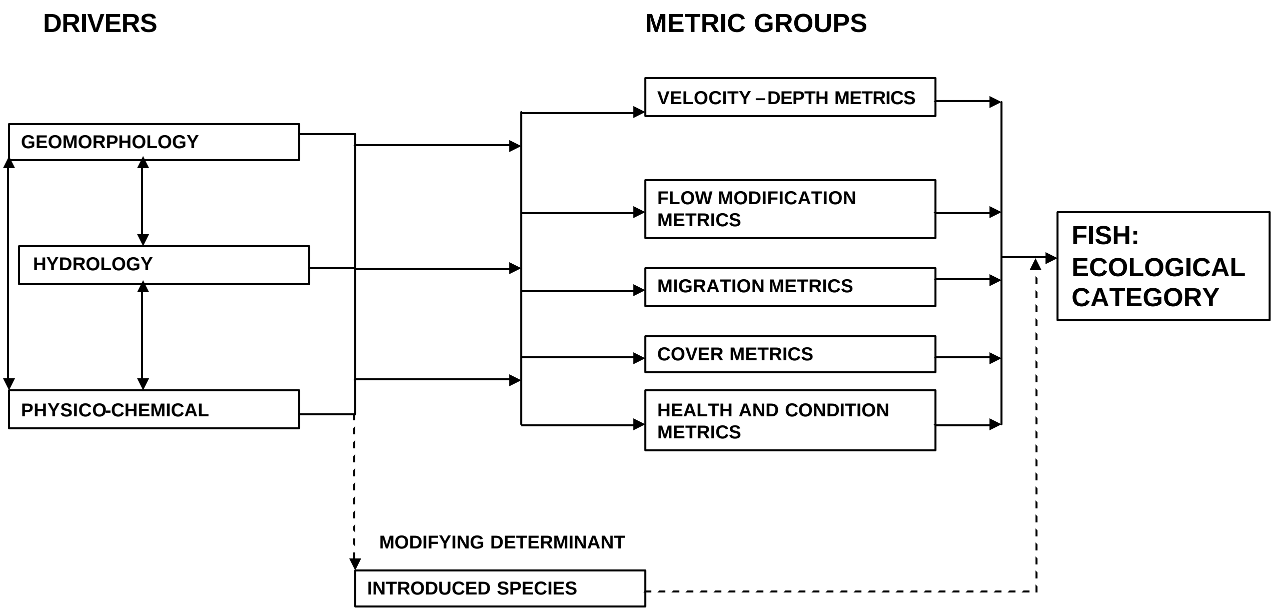

Figure 1.1 The relationship between drivers and fish metric groups

Although the FRAI uses essentially the same information as the FAII (Fish Assemblage Integrity Index; Kleynhans 1999), it does not follow the same procedure. The FAII was developed for application in the broad synoptic assessment required for the RHP and does not have a particularly strong cause-and-effect basis (cf. Kleynhans 1999). The purpose of the FRAI, on the other hand, is to provide a habitat-based cause-and-effect underpinning to interpret the deviation of the fish assemblage from the reference condition.

1.2 FISH ECOLOGY AND DRIVER INFORMATION REQUIREMENTS

To relate drivers and the resulting fish habitat template to the stress response of fish, the life-history requirements and environmental preferences of species must be considered. This is achieved by:

- Considering information on the life-history strategies and habitat preferences and requirements of each of the species in the assemblage. An expert -knowledge database that includes a semi-quantitative rating of the intolerances, cover preferences and flow (velocity-depth) preferences is available for the majority of South African freshwater fish species (Kleynhans, 2003) and was built into the FRAI model. Where this database is not sufficient, available literature on South African freshwater fish, as well as local experts, should be consulted.
- Habitat features are evaluated in terms of their suitability to the requirements of the species constituting the assemblage. This includes consideration of breeding requirements and early life-history stages, survival/abundance, frequency of occurrence in a river section, cover, health and condition and water quality.

This module is structured so as to provide the user hands-on access to the use of the FRAI model (developed in MS Excel 2003) with a condensed explanation of the rationale and ecological considerations on which it is based. The rationale of the FRAI is provided in Appendices, together with a simple example of its application and field forms that should be used to capture survey data.

Two versions of the FRAI will eventually be available. The version presented here is for general application. The River Health Programme (RHP) version will be customized for the RHP sites that have been identified in each Water Management Area (WMA) (Dallas 2005b) and for which reference species list and frequency of occurrence was determined (Kleynhans *et al.* 2007 in prep.).

1.3 STEPS IN THE DETERMINATION OF THE FISH EC

The eight steps followed in the calculation of the FRAI is indicated in Table 1.2.

Table 1.1 Main steps and procedures in the calculation of the FRAI

STEP	PROCEDURE
River section earmarked for assessment	As for study requirements and design
Determine reference fish assemblage: species and frequency of occurrence	• Use historical data & expert knowledge • Model: use ecoregional and other environmental information • Use expert fish reference frequency of occurrence database if available
Determine present state for drivers	• Hydrology • Physico-chemical • Geomorphology or • Index of habitat integrity
Select representative sampling sites	Field survey in combination with other survey activities
Determine fish habitat condition at site	• Assess fish habitat potential • Assess fish habitat condition
Representative fish sampling at site or in river section	• Sample all velocity depth classes per site if feasible • Sample at least three stream sections per site
Collate and analyze fish sampling data per site	Transform fish sampling data to frequency of occurrence ratings
Execute FRAI model	• Rate the FRAI metrics in each metric group • Enter species reference frequency of occurrence data • Enter species observed frequency of occurrence data • Determine weights for the metric groups • Obtain FRAI value and category • Present both modelled FRAI & adjusted FRAI.

1.3.1 Study of the river section earmarked for assessment

This step is common to the overall EcoStatus assessment and will provide the necessary spatial framework for FRAI determination.

1.3.2 Determine reference fish assemblage: species and frequency of occurrence

Two main sources of information to determine fish species expected to be present under reference conditions (actual or derived) can be used:

- Historical information from the river delineation under consideration can be used to provide an indication of reference conditions. This includes unpublished records and reports by local experts and organizations. Often distribution information can be related to conditions prior to major impacts on rivers, thereby providing a good indication of pre-impact conditions.
- In the absence of actual data for the river delineation, information on other river

reaches or neighbouring rivers can be used to compile a list of species expected under reference conditions. Filling of distribution gaps is also possible in the case of species such as *Anguilla* where absence in a river section can be used to derive presence upstream and downstream of such a section. In other cases the presence / absence of species within a different river in the same ecoregional context (Kleynhans, et al. 2005) and considerations such as stream order and altitude can be used to derive reference presence in the river delineation being considered. Distribution modeling will be considered for this purpose in the future. A prototype of this is under development.

Interpreting fish assemblage responses within the reference situation is based on the fish habitat segment approach (FHS, Kleynhans 1999). The FHS refers to a portion of a stream in which the fish assemblage remains “generally homogeneous due to the relative uniform nature of the physical habitat” (Ramm 1988). The boundaries of a fish habitat segment can be expected to vary according to the temporal and spatial variability (natural and human-induced) of environmental conditions in a segment. The purpose of defining fish habitat segments is to provide a basis that can be used to specify reference biological conditions in such segments with regard to the indigenous fish species that can be expected to occur, their frequency of occurrence, and general health and well-being. In addition, it is potentially possible to define reference habitat conditions that can be expected to occur at a broad level (Kleynhans 1999).

Reference species frequency of occurrence estimations can interrogate the expert opinion database that was compiled for all RHP sites in all WMAs, as well as some additional sites. This information is generally representative of the particular river ecoregion and geomorphological zone in which the site falls and will be built into the FRAI as a database (Kleynhans and Louw, in prep.).

Frequency of occurrence is rated according to the scale indicated in Table 1.2

Table 1.2 Frequency of occurrence ratings used in the calculation of the FRAI

FREQUENCY OF OCCURRENCE RATING	DESCRIPTION
0	Absent
1	Present at very few sites (<10% of sites)
2	Present at few sites (>10-25%)
3	Present at about >25-50 % of sites
4	Present at most sites (>50- 75%)
5	Present at almost all sites (>75%)

1.3.3 Determine present state for drivers

The purpose is to provide information on the fish response and associated habitat condition and *vice versa* (i.e. fish responses that are possible, given certain habitat conditions). This assessment considers the whole river section to be studied.

If information on the drivers is available, these should be used. Otherwise the IHI should be run for the river section (cf. **Appendix A.5** and Module G)

1.3.4 Sampling site selection

Site selection should consider the following:

- Habitat present at the site should be representative of the RU or river delineation under consideration. This means that the velocity-depth and cover classes at a site should be as representative of the river delineation as possible. However, for EC determination consideration should also be given to including sites with habitats that may actually be relatively uncommon in the river delineation, but which provide habitat for specialized or intolerant species or intolerant life-stages of some species (critical habitat). Information gleaned from such sites can provide a level of detail and sensitivity to the EC determination that may be lacking if only representativeness is considered.
- Preferably, sites should not be close to artificial structures such as bridges and weirs, as information from such sites may not necessarily be representative of the river delineation. Where no alternative is available, consideration of results from such sites should be regarded with caution. In certain cases sampling in weirs may be considered as the only option when the river is seasonal and permanent pool size is artificially enlarged by the construction of a weir. Downstream from such weirs, some limited flow may occur during the low flow season. Some fish species find habitat at such places and their presence may be useful for a limited assessment of river conditions (physico-chemical conditions for example, and even an indication that flows may at times be suitable for the completion of the life-cycle).
- Habitats at the site should be amenable to sampling. Factors such as the ease with which various sampling techniques such as electro-shocking and seine netting (including nets of various dimensions) can be used, should be considered. In the case of comprehensive and intermediate Reserve determination where detailed information is desirable, effort is usually focussed on a limited number of sites. Consequently the opportunity exists in such cases to do relatively intensive sampling (such as employing large seine nets and increasing sampling effort) than the case would be with rapid Reserves and for RHP purposes. Rapid Reserve determinations are usually limited to one or two sites in a reach that are easy and rapid to sample. The RHP strives to sample as many sites as possible as rapidly as possible in order to provide a representative or synoptic view of the health of the particular catchment.
- Factors such as accessibility and safety (in terms of dangerous animals and crime) are very important.

1.3.5 Fish habitat assessment at site

Arguments for the use of habitat as a surrogate in biological assessment can be found in **Appendix D.1.**

1.3.5.1 Habitat potential assessment

Habitat assessment refers to an evaluation of fish habitat potential (i.e., the potential that the habitat provides suitable conditions for a fish species to live there) at a site in terms of the diversity of velocity-depth classes present and the presence of various cover types at each of these velocity-depth classes. This provides a framework within which the presence, absence and frequency of occurrence of species can be interpreted. Habitat assessment includes a general consideration of impacts that may influence the condition or integrity of fish habitat at a site.

Table 1.3 indicates the metrics and metric groups of the FRAI in terms of velocity-depth and cover. The four velocity-depth classes each provide the setting for five different types of cover. These classes can easily be recognised by experienced field workers.

Estimates of the relative ecological importance of velocity-depth and cover classes (Table 1.4) at a site are partly based on the area covered (estimated as a percentage). Depending on the size of the river, a site with a low percentage of a particular velocity-depth and cover class can still actually cover a substantial area at a site. A low rating is unrealistic in such a situation. This is compensated for by judging the qualitative value of depth-flow classes for fish. Percentage of area covered is only used, therefore, as a guideline in this estimation.

General flow conditions at the time of sampling are qualitatively assessed following the approach in Table 1.5.

Table 1.3 Fish habitat assessment.
Abundance of velocity-depth classes and cover are estimated according to: : 0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant (cf Table 1.8 for specifications of classes)

SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation:	Overhanging vegetation:	Overhanging vegetation:	Overhanging vegetation:
Undercut banks & root wads:	Undercut banks & root wads:	Undercut banks & root wads:	Undercut banks & root wads:
Substrate:	Substrate:	Substrate:	Substrate:
Instream vegetation:	Instream vegetation:	Instream vegetation:	Instream vegetation:
Water Column:	Water Column:	Water Column:	Water Column:
Remarks:	Remarks:	Remarks:	Remarks:

Table 1.4 Aundance scoring of velocity-depth and cover classes (adapted from Rankin 1995)

Descriptor	Relative ecological value/abundance score	Occurrence (% of area covered)
None	0	0

Descriptor	Relative ecological value/abundance score	Occurrence (% of area covered)
Rare	1	0-5
Sparse	2	5-25
Common	3	25-75
Abundant	4	75-90
Very abundant	5	90-100

Table 1.5 Qualitative assessment of flow conditions during sampling (adapted from Dallas 2005a)

Water level	Description
Dry	No water flowing.
Isolated pools	Pools that have a trickle of water between them, but no evident flow.
Low flow (dry season base flow)	Water well within the active channel; water probably not touching the riparian vegetation.
Moderate flow (wet season base flow)	Water within the active channel; water likely to be touching riparian vegetation in places.
High flow	Water filling the active channel; water completely into riparian vegetation.
Flood	Water above active channel.

1.3.5.2 Habitat Condition

The purpose is to provide an indication of the deviation of the habitat from the reference condition. In contrast to the assessment of driver conditions or the IHI in a river section, fish habitat condition assessment is done for the site and modifications that have a direct influence on fish habitat at the site are considered.

Forms used for capturing IHI (ver.2) and EcoStatus driver data can be used for this. The RHP manual also provides forms that can be used for this (Dallas 2005a).

1.3.6 Fish sampling

The information provided here refers to minimum requirements. It is up to the operator to decide on the inclusion of additional information. Appendix D can be consulted on validation of the FRAI and sampling considerations.

Due to practical considerations, fish surveys are usually done during the low-flow period of the year.

Sampling effort and results are reported per velocity-depth class sampled. However, where the mosaic of velocity-depth classes makes it difficult or impossible to do this (combinations of fast-deep and fast-shallow classes, for instance), the dominant velocity-depth class should be used as the unit of reference for sampling effort, but the presence of other velocity-depth classes should also be indicated.

The following apparatus are often used for catching fish in the different velocity-depth classes:

- Fast-deep: An electrical shocking apparatus one operator and two dip net handlers) is used in such habitat types. Capture results are recorded as number of fish caught per time unit (minutes) (e.g. , AC 220v, 50 HZ, rated output=0.900 kva).
- Fast-shallow: Capture results are recorded as number of fish caught per time unit (minutes) with an electrical shocker
- Slow-deep: A large seine net (e.g. 70 m long, 1.5 m deep, mesh size 2.5 cm) can be used. A cast net, (diameter = 1.85 m, mesh size = 2.5 cm) can used in pools not suitable for beach seining. Capture results are recorded as number of fish caught during each effort
- Slow-shallow: A small seine net (5 m long, 1.5 m deep, mesh size = 1 mm) can be used to sample fish. An electrical shocking apparatus should preferably be used. Capture results are recorded as number of fish caught during each effort with a net, or the number of fish caught per time unit (minutes) with an electroshocker.

Although all these sampling methods are mentioned as options, it has been generally recommended that electrical shocking apparatus be used for fish integrity assessment (Pont, et al.2006; Kleynhans 2007, **Appendix D**). Apparatus used in the different velocity-depth classes have not yet been standardized nationally. It can be expected that standardization will also have to be considered in terms of regional aspects such as EcoRegions, stream types, stream size and the fish species present. Manpower available for surveys will also play a role in the type of apparatus that can be used. Prior to any standardization, it is important that the apparatus and effort spent in sampling fish be kept similar in a particular river and for a particular study. This also applies to monitoring surveys.

All species sampled are counted and anomalies such as tumours, external parasites and other abnormalities are indicated. Although fish length is usually not measured, age groups can roughly be categorized according to juveniles and adults.

Although guidelines for representative sampling at a site needs specification for streams of different sizes and different fish species richness, sampling at sites in the Crocodile River (Kleynhans 1999) and Elands River (**Appendix D**) followed the following general approach:

- Standard electro-shocking effort: 60-80 minutes per site (that is, time electricity was actually applied in the water). It is recommended that where possible, at least three stream sections be sampled per site (e.g., 3 sections each sampled for 20 minutes) and that the results be recorded separately. The three river sections should be spaced to avoid results from the one influencing the other. (Kleynhans 2007).
- Standard small seine (see above) net effort: 2 efforts per site.
- Standard large seine (see above) net effort: 3 efforts per site.
- Cast net (see above) effort: 20 throws per site.

However, this is only generalization, and the effort will obviously also depend on the size of the river as well as the species richness. While electro-shocking is the sampling method of preference in all wadeable habitats and the RHP in particular, surveys for determination of the ecological reserve may possibly also make use of seine nets.

Other fish sampling methods (such as fish traps and fish fykes) can be used where suitable. Destructive sampling methods such as fish poisons and gill nets are not used. It is important to note that all velocity-depth classes are not necessarily present or possible to sample at a site, and that all sampling methods and apparatus are not necessarily applied at a site.

The RHP Rivers Database is currently under revision. It may be suitable for capturing certain aspects of the fish sampling but also incorporates data from the perspective of the RHP which may not be completely relevant to the EcoClassification-EcoStatus process followed in ecological Reserve determinations. The forms provided in this document (**Appendix B**) should be used to capture relevant fish related data.

The SURVEY_DATA sheet of the FRAI model provides a convenient way to summarize fish sampling data and have it available when the model is run. This sheet is an abstract of the fish sampling forms in the RHP manual (Dallas 2005a).

1.3.7 Collate and analyze fish sampling data per site

Sampling data at different velocity-depth classes should be kept separate for analysis. If only certain velocity-depth classes were sampled, it is important to use the data and make conclusions within this limitation. This means that if, say slow-deep habitat was not sampled, species that would occur predominantly in this velocity-depth class should be excluded from the assessment in terms of the species expected under reference conditions. The sample must therefore be as representive as possible and reference conditions should only be set for the species that would occur in the habitats that were actually sampled.

Fish sampling data per site or per stream length sampled per site, is transformed to frequency of occurrence ratings. Where three or more sections were sampled per site, the following calculation should be done to transform data into frequencies of occurrence on a rating scale of 0-5 by:

$$FROC = (Nsp/Ns) \times 5$$

Where:

FROC= Frequency of occurrence of a species

Nsp=Number of sites in the reach or sampling points at a site where a species was sampled.

Ns=Number of sites sampled in the reach or number of points sampled at a site.

5= Maximum frequency of occurrence of a species.

The same calculation can be followed where more than 1 site were sampled per river reach.

See Table 1.2 for the interpretation of frequency of occurrence ratings.

1.4 EXECUTE THE FRAI MODEL

The FRAI model makes use of the fish intolerance and preference database that was compiled in 2001 (Kleynhans 2003). This information was built into the FRAI. **Appendix A.4** provides information on the database and it structure. The approach followed in the ranking, weighting and rating of metric groups is similar to that indicated in Module A: EcoStatus. A large component of the FRAI is based on an automated calculation of ranks, weights and ratings (**Appendix A.6**). However, where this needs to be done manually the basic question is: Which metric would make the most significant contribution to improving (or degrading) the metric groups and the PES?

Table 1.6 provides a summary of metrics and metric groups, as well as their specification and relevance for fish assemblage assessment and guidelines for the rating of metrics.

Table 1.7 provides guidelines for the assessment of the impact of introduced species.

Table 1.8 provides a description of metric groups, metric responses, specification and relevance.

Table 1.9 indicates all the FRAI model sheets that are used during execution of the FRAI model, their purpose and relevance and provides a concise guideline for the application of the model.

Examples of all FRAI sheets are indicated in **Appendix C.**

Table 1.6 Metric groups and considerations for their assessment based on habitat indicators and species responses

<table>
<tr><th rowspan="2">METRIC GROUP (EXCEL SHEET IN MODEL)</th><th colspan="2">CONSIDERATIONS</th><th rowspan="2">SPECIES RESPONSE METRICS:
RATING CRITERIA</th></tr>
<tr><th>HABITAT INDICATORS:
COMPARED TO REFERENCE</th><th>SPECIES RESPONSE OBSERVED OR DERIVED FROM HABITAT INDICATORS: COMPARED TO REFERENCE</th></tr>
<tr><td>Velocity-depth (VEL_DEPTH)</td><td>Changes in:
Fast-deep, fast-shallow, slow-deep and slow-shallow. Causes – changes in hydrology; zero flows, base flows, moderate floods and freshes. Seasonality. Changes in sediment capacity and supply (sedimentation and scouring)</td><td rowspan="4">Depends on reference species in the fish assemblage able to utilize velocity-depth, cover, modified flow or physico-chemical conditions.</td><td rowspan="4">-5 or 5: Extreme loss (absent)/increase (completely dominant) from reference
-4 or 4: Serious loss/increase from reference
-3 or 3: Large loss/increase from reference
-2 or 2: Moderate loss/increase from reference
-1 or 1: Small loss/increase from reference
0: No change from reference</td></tr>
<tr><td>Cover (COVER)</td><td>Changes in:
1. Overhanging vegetation. Causes – altered water levels, bank erosion or physical destruction of overhanging vegetation. Increase in vegetation due to increased nutrients and alien vegetation.
2, Undercut banks and root wads. Causes – altered water levels, bank erosion or physical destruction of overhanging vegetation.
3. Particular stream substrate type. Causes – changes in sediment transport (supply & capacity), benthic algal growth due to increased nutrients.
4. Instream vegetation. Causes – invasive alien macrophytes, changed water levels, physical destruction.
5. Water column. Causes – altered water levels or loss of depth due to sedimentation (in pools).</td></tr>
<tr><td>Flow Modification (FLOW_MOD)</td><td>Changes in hydrology:
1.Increase or decrease in no-flow conditions
2. Increase or decrease in low-flow conditions
3. Increase or decrease in moderate events
4.Increase or decrease in events (high flow, floods)
Change in seasonality is considered for each.</td></tr>
<tr><td>Physico-Chemical (PHYSCHEM)</td><td>Changes in:
1. pH
2. Salts
3. Nutrients
4. Temperature
5. Turbidity
6. Oxygen
7. Toxics</td></tr>
<tr><td>Migration (MIGRATION)</td><td>Any modification that results in the fragmentation of fish populations is considered.
The presence and extent of the following are considered in evaluating the impact on and response of migratory species –
1. Weirs and causeways
2. Impoundments
3. Physico-chemical barriers
4. Hydrological modifications</td><td>Depends on reference species in the fish assemblage</td><td>0: None, or no potential impact on movement.
1: Small; limited with small potential impact.
2: Moderate; notable and with potential impact.
3: Large; clear potential impact.
4: Serious; clear and serious potential impact.
5: Extreme; clear and critical potential impact.</td></tr>
</table>

Table 1.7 Guidelines for the assessment of the impact of introduced species

METRIC GROUP	IMPACT GUIDELINES	FREQUENCY OF OCCURRENCE GUIDELINES
Introduced species (INTRO)	Predaceous species / habitat modifying species with a critical impact on native species = 5 Predaceous species / habitat modifying species with a serious impact on native species = 3-4 Predaceous species / habitat modifying species with a moderate impact on native species = 2-1 Predaceous species / habitat modifying species with no impact on native species, or are absent completely = 0	0 = absent 1 = present at very few sites (<10%) 2 = present at few sites (>10-25%) 3 = present at about >25-50 % of sites 4 = present at most sites (>50-75%) 5 = present at almost all sites (>75%)

Table 1.8 Description of fish metric responses, specification and relevance (cf. Appendix A.5)

METRIC GROUP (EXCEL SHEET IN MODEL)	METRICS	METRIC SPECIFICATION AND RELEVANCE
Velocity-depth (VEL_DEPTH)	Response of species with: 1. High to very high preference for fast-deep conditions 2. High to very high preference for fast-shallow conditions 3. High to very high preference for slow-deep conditions 4. High to very high preference for slow-shallow conditions (Based on Oswood and Barber 1992)	Interpreted as hydraulic habitat types, Jordanova, et al. (2004): 1.Fast-deep: >0.3 m deep; velocity >0.3m/s (deep runs, rapids and riffles). 2. Fast-shallow: <0.3 m deep; velocity >0.3m/s (shallow runs, rapids and riffles) 3. Slow-deep: >0.5 m deep; velocity <0.3m/s (deep pools and backwaters) 4. Slow-shallow:<0.5 m deep; velocity <0.3m/s (shallow pools and backwaters)
Cover (COVER)	Response of species with: 1, High to very high preference for overhanging vegetation. 2. High to very high preference for undercut banks and root wads 3. High to very high preference for a particular stream substrate type. 4.High to very high preference for instream vegetation 5. High to very high preference for the water column.	1. Overhanging vegetation: Thick vegetation overhanging water by approximately 0.3 m and not more than 0.1 m above the water surface (Wang et al. 1996)). 2. Undercut banks and root wads: Banks overhanging water by approximately 0.3 m and not more than 0.1 m above the water surface (Wang et al. 1996). 3. Stream substrate type: The degree to which various substrate components (rocks, boulders, cobbles, gravel, sand, fine sediment and woody debris ("snags")) provide cover for fish are judged qualitatively. No detailed assessment of the stream substrate and estimation of the contribution of individual components are attempted. The composition of the substrate is handled in a descriptive manner (Kleynhans 1999). 4. Instream vegetation: .Submerged and emergent plants. A qualitative estimate made of the cover value for fish. 5. Water column: Decreasing risk of aerial predation. Sufficient water depth and size of species important.
Flow Modification (FLOW_MOD)	Response of species: 1. Intolerant of no-flow conditions. 2. Moderately intolerant of no-flow conditions. 3 .Moderately tolerant of no-flow conditions. 4.Tolerant of no-flow conditions.	This metric group is interpreted based on the level of requirement that various species (or life-stages of a species) have for flowing water. The aspects of the impact of flow modification on physical habitat attributes are considered under other metric groups such as cover and velocity-depth classes.
Physico-Chemical	Response of species:	Health and condition of species are a reflection of the well-

METRIC GROUP (EXCEL SHEET IN MODEL)	METRICS	METRIC SPECIFICATION AND RELEVANCE
(PHYSCHEM)	1. Intolerant of modified physico-chemical conditions. 2. Moderately intolerant of modified physico-chemical conditions. 3. Moderately tolerant of modified physico-chemical conditions. 4. Tolerant of modified physico-chemical conditions.	being of fish. Adverse environmental conditions (caused by decrease in food availability, modified physico-chemical conditions, decrease in preferred habitat, for instance, all of which may be related to flow alteration) may result in physiological stress conditions that impact on the immune system of species, resulting in deterioration of health and condition. For the FRAI, modified physico-chemical conditions are the primary consideration.
Migration (MIGRATION)	Response of species: 1. Requiring catchment scale movements. 2. Requiring movement between reaches of fish habitats segments. 3. Requiring movement within a reach or fish habitat segment.	The severity of the impact of obstruction of fish movement on the distribution, abundance and survival of a fish species in the particular river forms the basis of the assessment. Migration can be related to breeding, feeding and survival life-history strategies
Introduced species (INTRO)	The impact of introduced species: 1. Competing or predaceous species. 2. Frequency of occurrence of predaceous or competing species. 3. Habitat modifying species. 4. Frequency of occurrence of habitat modifying species.	Introduced species may have a dominant impact on the native fish assemblage, while the physical drivers may actually be in a close to reference condition. They can have a severe effect on the habitat structure (indirectly influencing the natural fish assemblage) and the fish assemblage structure itself through predation. Modified habitat conditions may also be to the advantage of introduced species.

Table 1.9 FRAI model: Sheets, sequence, purpose and operation.
Grey-shaded blocks in the model indicate where values should be entered. All other blocks are protected.

FRAI MODEL SHEET	PURPOSE AND OPERATION
SURVEY DATA	Capturing and collation of data. The reference species list as well as the species sampled should be indicated here as well as the transformation of results to frequency of occurrence ratings.
SCIENTIFIC NAMES	The table provides the 4 letter abbreviation of freshwater species scientific names. Scientific names are also provided. Only for lookup purposes. Although the genus names of some species have changed (such as some large yellowfish changed from *Barbus* to *Labeobarbus*) the abbreviation used is the previous one. The scientific names have been updated
SPP INTOL_PREF	The 4 letter species abbreviation should be filled in here. Information on intolerance and preferences as well as migratory requirements will then be listed. Only species native to the stream should be entered in this species list (i.e. the reference species list). Other species (i.e. introduced species) abbreviations can be entered to provide information on their requirements, but should be deleted when the information has been perused. This species list as well as the intolerance and preference information are carried over to other sheets for calculation.
REF_OBS_SPP	The species entered in the previous sheet will be listed here. The reference frequency of occurrence of these species should be estimated according to the information in Kleynhans *et al*. 2007 (in prep.) if the river section and site under investigation is similar to the one in the Database. The frequency of occurrence is entered for each species (e.g 1-5; cf. Table 1.2). Enter the observed species frequency of occurrence (e.g. 0-5 in this case; cf. Table 1.2). If there are good indications that a species were undersampled due to difficult habitat conditions (e.g. eels) consider increasing the frequency of occurrence based on habitat integrity

FRAI MODEL SHEET	PURPOSE AND OPERATION
	information. However, the original sample information should be kept in the SURVEYDATA sheet.
INTRO_ALIEN	Two tables are provided: (1) Predaceous alien species (2) Habitat modifying or competing species. Indicate with a Y/N whether the species is present. A potential impact value (0-5) will appear. Only alien species should be indicated. Indigenous species that were introduced extra-limitally, do not appear in the tables and should be assessed seperately
VEL_DEPTH (metric group)	Three tables: 1. Change in velocity-depth classes from the reference (cf. Table 1.8 for class specification) for the river section. Based on commonness of class under reference, its weight (most common=100%, rest comparatively lower) and the rating (from extremes: -5 and 5; reference = 0; cf. Table 1.6). 2. Automated calculation of the change in the four metrics based on the derived fish response according to intolerance and preference ratings. Consult the appendix for information on the approach followed for this. No entries are required. 3. A table where the automated calculation (Table 2) can be adjusted. Adjustment is based on the consideration of the change in velocity depth classes (Table 1). The ranks, weights and ratings can be modified here.
COVER (metric group)	Three tables (same approach as for VEL_DEPTH metric group): 1. Change in cover metrics from the reference. 2. Automated calculation. No entries are required. 3. A table where the automated calculation (Table 2) can be adjusted.
FLOW_MOD (metric group)	Three tables (same approach as for VEL_DEPTH metric group): 1. Change in flow modification metrics from the reference. 2. Automated calculation. No entries are required. 3. A table where the automated calculation (Table 2) can be adjusted.
PHYSCHEM (metric group)	Three tables (same approach as for VEL_DEPTH metric group): 1. Change in physico-chemical metrics from the reference. 2. Automated calculation. No entries are required. 3. A table where the automated calculation (Table 2) can be adjusted.
MIGRATION (metric group)	Two Tables: 1. Stream modifications that can limit fish movement. Severity rated (-5 to 0). 2. Response of species observed or derived to have occurred due to migration limitations. The SPP INTOL_PREF sheet should be consulted for migratory requirements (Kotze, in prep)
INTRO (metric group)	Two Tables: 1. Introduced species impact. This should be ranked, weighted and rated. 2. This Table provides a summary of the INTRO_ALIEN sheet.
METRIC GROUP WEIGHTS	Metric group weight are determined according to a Analytical Hierarchical Procedure (AHP)(Saaty 1980; US Army Corps of Engineers 1980). The purpose of this approach is to provide a reasonably objective way to determine the weights of metric groups. An AHP approach is followed where the metric groups are compared pairwise on a 0 – 10 scale with 0.5 intervals. Metric group weights are determined in the FRAI model sheet: METRIC GROUP WEIGHTS. The objective is to determine the weight of various metric groups as it relates to the natural attributes and requirements of the reference fish assemblage. Introduced species are not a natural attribute or requirement and is considered as an impact that will only decrease the frequency of occurrence of native species. <u>Rationale</u> Considering the natural characteristics of the fish assemblage and its habitat, and when comparing a pair of fish metric groups, Which member in the pair would contribute most to a decline or improvement in the fish assemblage integrity if it was to change for whatever reason? <u>Approach</u>: The pair with the highest importance in this situation would then receive the highest rating out of 10 with the residue being awarded to the member with the lower contribution. If both members are equally important, both would receive a rating of 5 <u>Considerations</u>:

FRAI MODEL SHEET	PURPOSE AND OPERATION
	Metric groups: VEL_DEPTH, COVER, FLOW_MOD, PHYSCHEM, the number of species in each metric group, their intolerances as well as habitat characteristics should be taken as the basis of comparison between members of a pair. Metric group: MIGRATION, the number of species with various migration requirements should be considered. Metric group: INTRO, the characteristics and distribution of the introduced species should be considered together with the vulnerability of the indigenous species. This refers only to species that have already been introduced to system and not to species that can potentially be introduced.
EC RESULTS	The results (Ecological Category) of the FRAI assessment is provided here in terms of automated model assessment as well as the adjusted calculation. Both values should be reported with explanations as to the reasons for adjusting the automated assessment. A table with summary information on the species in the assemblage.

2 FRAI INTERPRETATION OF EC RESULTS

Two examples of the FRAI EC results will be interpreted here. Only the contribution of metric groups' values to the FRAI index value will be discussed in terms of its significance and implications.

2.1 EXAMPLE 1

Table 2.1 indicates the weights of the different metric groups. According to this, the flow modification metric group carries the most weight followed by the velocity-depth and physico-chemical metric groups. All of these have a strong link with flow. No introduced species are present..

Table 2.1 Example 1, Metric group weights

METRIC GROUP	WEIGHT (%)
Velocity-depth	92.65
Cover	82.35
Flow modification	100.00
Physico-chemical	98.53
Migration	55.88
Impact of introduced species	0.00

Table 2.2 indicates the EC results of the FRAI assessment. According to this species with a high preference for clear, flowing water and perennial flow decreased in frequency of occurrence compared to the reference. Habitat integrity assessment indicated that the flow in the river decreased considerably with a decrease in fast flowing habitats during the breeding season in particular. According to this information it is suspected that the decrease in the fish EC is primarily due to modified flow conditions which had a detrimental impact

Table 2.2 Example 1, FRAI EC results.

	AUTOMATED	
FRAI (%)	65.6	
EC: FRAI	C	
	ADJUSTED	
FRAI (%)	65.6	
EC: FRAI	C	

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE	PES:OBSERVED & HABITAT DERIVED FREQUENCY OF OCCURRENCE
CPRE	CHILOGLANIS PRETORIAE VAN DER HORST, 1931	5.00	2.00
CBIF	CHILOGLANIS BIFURCUS JUBB & LE ROUX, 1969	3.00	1.00
AURA	AMPHILIUS URANOSCOPUS (PFEFFER, 1889)	5.00	1.00
AMOS	ANGUILLA MOSSAMBICA PETERS 1852	3.00	2.00
BPOL	LABEOBARBUS POLYLEPIS BOULENGER, 1907	4.00	3.00
BARG	BARBUS ARGENTEUS GÜNTHER, 1868	5.00	2.00
ANAT	AMPHILIUS NATALENSIS BOULENGER, 1917	3.00	1.00
BMAR	LABEOBARBUS MAREQUENSIS SMITH, 1841	5.00	4.00

2.2 EXAMPLE 2

Table 2.3 indicates the weights of the different metric groups. The same native species as in example 1 are present. In this case a predaceous species with severe ecological impact was introduced.

Table 2.3 Example 2, Metric group weights.

METRIC GROUP	WEIGHT (%)
Velocity-depth	91.38
Cover	79.31
Flow modification	100.00
Physico-chemical	98.28
Migration	48.28
Impact of introduced species	86.21

Table 2.4 indicates the EC results of the FRAI assessment. The introduction of a predaceous species with a severe impact resulted in a considerable decrease in the frequency of occurrence of the reference fish assemblage with a consequent decrease in the FRAI value and category.

Table 2.4 Example 2, FRAI EC results

	AUTOMATED	
FRAI (%)	44.4	
EC: FRAI	D	
	ADJUSTED	

FRAI (%)	44.4		
EC: FRAI	D		
ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	**SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)**	**REFERENCE FREQUENCY OF OCCURRENCE**	**PES:OBSERVED & HABITAT DERIVED FREQUENCY OF OCCURRENCE**
CPRE	CHILOGLANIS PRETORIAE VAN DER HORST, 1931	5.00	1.00
CBIF	CHILOGLANIS BIFURCUS JUBB & LE ROUX, 1969	3.00	0.00
AURA	AMPHILIUS URANOSCOPUS (PFEFFER, 1889)	5.00	0.00
AMOS	ANGUILLA MOSSAMBICA PETERS 1852	3.00	2.00
BPOL	LABEOBARBUS POLYLEPIS BOULENGER, 1907	4.00	2.00
BARG	BARBUS ARGENTEUS GÜNTHER, 1868	5.00	1.00
ANAT	AMPHILIUS NATALENSIS BOULENGER, 1917	3.00	1.00
BMAR	LABEOBARBUS MAREQUENSIS SMITH, 1841	5.00	3.00

3 FRAI: PREDICTIVE USES

Using the FRAI model, it is possible to make some qualitative predictions as to how the fish assemblage is likely to respond when changes in driver components, and specifically particular driver metrics, are changed. Essentially these predictions will be of a conceptual nature, with uncertain confidence of how close to reality they actually are.

Two questions can be posed as an example:

1. How would the fish assemblage react if certain flow characteristics were changed?

This may be an increase in low flow duration compared to the current situation and may, for instance, occur during the spawning season. The attributes of the assemblage and the severity of increase in low flow periods would be key considerations. It would then be possible to predict how species dependent on particular habitat conditions, would respond to such changes when impacts on their spawning and nursery habitat, as well as physico-chemical conditions are considered.

2. What would an increase or decrease in the fish assemblage integrity relate to?

In such a case, one would attempt to relate such a change to particular driver changes. The PES of the fish assemblage may, for instance, be lower than desired or required (the REC). To increase the PES one would focus on particular metric groups and metrics in a group that were indicated by the FRAI as being prominent in the decrease of the assemblage integrity. To improve such metrics and metric groups would entail improving environmental conditions for the associated species and this would than be related to certain driver changes.

4 FRAI USES WITHIN MONITORING

The purpose of using the FRAI within a monitoring framework relates to posing hypotheses as to the REC for the river and the fish. With such an approach the FRAI can be used in a predictive manner (cf. 3) to derive an REC as well as alternative ECs. These could then be used as the basis of monitoring the attainment of a particular REC in terms of the fish assemblage by considering the response of particular metrics and metric groups when an ecological Reserve is implemented. Monitoring will provide the basis to determine if the ecological objectives are being achieved in terms of the fish assemblage as it was derived based on the FRAI. Adaptive environmental monitoring and assessment can provide the framework within which the monitoring information can be used to re-assess and review the attainment of the ecological objectives for the river (Holling 1978, Rogers and Bestbier 1997, Roux et al. 1999).

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A APPENDIX A: RATIONALE FOR FISH ASSEMBLAGE ASSESSMENT

A.1 FISH STRESS

Fish stress is described and characterized as follows -

- It is viewed as a condition where the response to a stimulus or stressor results in a state where an extension of the physiological condition occurs beyond the normal resting phase (Brett, 1958).
- Stress is seen as a state of threatened homeostasis that is re-established by a complex of adaptive responses (Chrousos, 1998). In this sense, response to stress is an adaptive mechanism that permits the fish to cope with stressors in order to maintain its normal or homeostatic state and is not necessarily detrimental to the fish.
- The mechanism of stress response is complex and involves primary (neuroendocrine), secondary (metabolic) and tertiary responses. Tertiary responses involve whole-animal performance characteristics (growth, swimming capacity and disease resistance) and modified behavioural patterns (feeding and aggression). These three levels of stress response are integrated and interregulated (Barton *et al*., 2002).

Stressors have been grouped according to Barton *et al*., 2002 -

- Chemical (e.g., contaminant and pollution exposure, low oxygen concentrations and acidification),
- Physical (e.g., handling capture, confinement and transport),
- Perceived (e.g., stimuli evoking startle response and presence of a predator)
- The general adaptation syndrome (Selye 1950) states that a fish passes through three stages of response to stress -
- An alarm phase during which the fish perceives the stimulus and recognition of it as a threat to homeostasis,
- A resistance stage when the fish mobilizes its resources to adjust to the disturbance and maintain homeostasis,
- An exhaustion phase that follows if the fish, in spite of activating a stress response, is incapable of coping with the disturbance.

The first two phases are manifested by measurable physiological changes. The last phase is the maladaptive phase, usually associated with the development of pathological states that influence the health and condition of fish and that can eventually result in mortality (Barton *et al*. 2002).

Studies have shown that repeated exposure to mild stressors can habituate fish and attenuate the neuroendocrine and metabolic responses to subsequent exposure to stressors (Reid *et al*. 1998). However, if the intensity of the stressor is very severe or long-lasting, physiological response mechanisms may be compromised and can become detrimental to the fish's health and well-being, causing "distress" (Barton *et al*., 2002). In this context the response of the immune system must also be considered. If this system is compromised, increased susceptibility to diseases will occur. Overcrowding, rapid changes in temperature, salinity and dissolved oxygen are common stressors affecting immuno-compotence in fish (Rice and Arkoosh, 2002).

The detailed relationship between stress that impacts individual fish, then the population and eventually the assemblage or community, is highly complex. However, for the purposes of predicting and assessing the response of fish, it is assumed that stress on an individual fish will eventually be manifested in the population and assemblage.

A.2 FISH HABITAT

The quantity and quality of available habitat can be used as an indirect indication of the effect of stressors on individual fish and populations. This relationship between habitat condition and fish condition is possible because characteristics of fish evolve in response to the properties of habitats. The habitat is the template on which life-history strategies are formed (Southwood, 1977; DeAngelis & Curnutt, 2002). Following this, predictions on the traits of individual fish species present (as well as assemblage characteristics such as species richness) can be made on basis of the habitat.

For the assessment and evaluation of the fish assemblage response to habitat conditions, it is important that fish habitat and its components be properly defined (Bain & Stevenson, 1999) -

- Habitat: "specific type of place within an ecosystem occupied by an organism, population or community that contains both living and nonliving components with specific biological, chemical, and physical characteristics including the basic life requirements of food, water, and cover or shelter."
- Habitat component: "single element (such as velocity, depth, or cover) of the habitat or area where an organism lives or occurs. Component is synonymous with attribute."
- Habitat diversity: The number of different habitat types within a given area.

More specifically for the purposes of this study, habitat is specifically defined as - Any particular combination of velocity, depth, substrate and associated cover (such as marginal and overhanging vegetation, undercut banks, root wads, aquatic macrophytes, water column), physico-chemical attributes (such as temperature, oxygen concentration, turbidity) and biological attributes (that is, food sources) that provide a fish with its life-stage requirements at that particular point in time and geographically.

Within the scope of this definition, consideration should be given to the duration of the combination of these habitat features to satisfy the requirements of particular life-history stages of a species during particular seasons or events.

A.3 INTERPRETATION OF FISH ASSEMBLAGE RESPONSES TO HABITAT CHANGES

Over evolutionary time, A particular habitat or a range of habitats used by fish species shape their characteristics. It follows that species do best in the habitats in which they evolved and that changes in habitat extent and characteristics can impose various levels of stress on populations. Changes in habitat may, therefore, be indicators of the well-being or condition of particular species or assemblages (DeAngelis & Curnutt, 2002).

A particular combination of habitat features may not necessarily provide optimum conditions for the specific life-history stage requirements of a fish at the time, frequency, duration and place when they are required. This may be the result of anthropogenic impacts on the habitat (such as flow reduction, sedimentation of habitat, and physico-chemical changes), or it may even be a situation where a particular species occurs only marginally and is, even under natural conditions existing under sub-optimal conditions. This relates to stress, and will result in compensatory mechanisms being activated in order to establish homeostasis in response to these stressors. It follows that species occurring marginally, and which are naturally already subject to higher stress than under optimal conditions, will have a narrow stress buffer. In such as case, a relatively “small” decrease in the flow may, for example, already result in a pronounced stress effect due to particular critical habitats or critical habitat features being in limited supply naturally. It follows that differences in the requirements of different species constituting the fish assemblage may result in a change in the assemblage when the natural flow regime changes (including natural disturbance regimes).

It is essential to consider all habitat features, both flow and non-flow related, even if they are difficult to measure and predict quantitatively (types of cover, physico-chemical attributes, flow, the food source, for instance). Even when flow and the resulting hydraulic habitat seems suitable for a particular EC and species requirements, responses of features such as temperature, oxygen and the available food source may be so negative that the ability of a species to adapt to such conditions may become severely compromised.

Habitat assessment as an indirect indicator of stress as such can never be an ideal replacement for direct measurement of fish condition. However, it is acknowledged that measuring responses of fish populations and assemblages to environmental disturbance can be very difficult, and that surrogate approaches (even if they are imperfect) are needed wherever possible to assess these changes (DeAngelis & Curnutt, 2002).

The approach followed here to assessing fish response to driver characteristics is based on a qualitative combination of species attributes, habitat resulting from driver changes and fish survey information.

A.4 FISH INTOLERANCE AND HABITAT PREFERENCE DATABASE

The sections that follow address the information contained in a database that was compiled in 2001 and the approach that was followed to obtain this information (Kleynhans 2003). The database information used in the FRAI is contained in the FRAI spreadsheet model.

A.4.1 Species intolerance ratings

Intolerance in this context refers to the degree to which a species is able to withstand alterations of the environmental conditions under which it occurs. This includes modification of physical habitat characteristics (such as depth, velocity, marginal vegetation, bottom substrate, food source), as well as physico-chemical characteristics of the water. Habitat preferences provide a large amount of information that is useful in determining the degree to which a species can be regarded as tolerant, moderately intolerant and intolerant. Experimental information on the intolerance of various South African fish species is, however, largely lacking, and the assessment of the degree to which species are tolerant or intolerant usually has to be based on field observations and expert knowledge.

Two components are taken into account in estimating the intolerance of fish species for calculation of the FRAI: requirement for flowing water during different life-stages; and association with unmodified physico-chemical conditions. Both of these aspects are scored for a species according to -

- Low requirement / specialisation (rating = 1),
- Moderate requirement / specialisation (rating = 3) and
- High requirement / specialisation (rating = 5).

Intolerance ratings for each of the two components provided by experts are averaged and the average interpreted as -

- 1-2 = Tolerant
- >2-3 = Moderately tolerant
- >3-4 = Moderately intolerant
- >4-5 = Intolerant

The assessment of the two components of species intolerance is approached in the following way:

A.4.1.1 Requirements for flowing water during different life-stages

Species differ with regard to their requirements for flowing water during different life-stages. The work of Crass (1964), Gaigher (1969), Pienaar (1978), Kleynhans (1984), Bell-Cross and Minshull (1988), Skelton (1993), Weeks *et al.* (1996), and

Russel and Rogers (1998) should be consulted for information on habitat preferences. Three general groups are distinguished –

- Species not requiring flow during any part of the life-cycle. However, increased habitat suitability and availability resulting from increased flow can be expected to benefit such species. With some species, flow will stimulate breeding activities and stimulate migration. Score = 1
- Species requiring flow during certain phases of the life-cycle - to breed in particular habitats (often fast flows) for instance, or make nursery areas with suitable cover available. Generally, increased habitat suitability and availability resulting from increased flow can be expected to benefit such species. Flow will stimulate breeding activities and stimulate migration. Score = 3
- Species requiring flow during all phases of the life-cycle. Often prefer fast flow and clear water and use these conditions both for breeding and feeding purposes. Score = 5

A.4.1.2 Requirement for unmodified physico-chemical conditions

Very little information on the physico-chemical requirements of South African fish is available. Consequently, resort has to be made to the previously-observed associations of certain fish species with modified and unmodified physico-chemical conditions as compared to the reference. This can take the form of the association of fish species with different habitats in a variety of geographical areas. For instance, the preference of some species for fast flowing, turbulent, clear water tend, in natural or minimally developed catchments, to be associated with habitats with unmodified physico-chemical conditions. Conversely, in catchments that are extensively developed and the water often polluted, some species will still be able to survive in habitats such as pools, which may even be stagnant. It is surmised that these species are relatively tolerant to impaired physico-chemical conditions. This approach is similar to that followed by Lyons *et al.* (1995) in information-scarce situations in Mexico. The following general rating approach is followed -

- Species that can survive and breed under severely modified physico-chemical conditions - Score = 1.
- Species that can survive and breed under moderately modified physico-chemical conditions -. Score = 3.
- Species that require largely unmodified physico-chemical conditions to survive and breed - Score = 5.

Due to the lack of any detailed information this approach must be seen at best as giving an indirect and relative indication of physico-chemical requirements.

A.4.2 Species preference ratings

A.4.2.1 Velocity-depth preferences

Fish species velocity-depth preferences were scored according to the preference for the four velocity-depth classes (cf. 1.2.3) –

- Slow-shallow
- Slow-deep
- Fast-shallow
- Fast-deep

Each of these is scored according to –

- 0 = No preference/irrelevant
- 1 = Low preference
- 3 = Moderate preference
- 5 = High preference

Velocity-depth preferences provided by experts are averaged and the average interpreted as –

- 0 = No preference / irrelevant
- >0 -1= Very low preference – coincidental?
- >1-2 = Low preference
- >2-3 = Moderate preference
- >3-4 = High preference
- >4-5 = Very high preference

A.4.2.2 Cover preferences

These features are considered to provide fish with the necessary cover (such as refuge from high flow velocity, predators and high temperatures) to utilise a particular velocity-depth class (Kleynhans 1999):

- Overhanging vegetation
- Undercut banks and root wads
- Stream substrate
- Aquatic macrophytes
- Water column

Each of these is scored according to:

- 0 = No preference / irrelevant
- 1 = Low preference
- 3 = Moderate preference
- 5 = High preference

A.5 THE RELATIONSHIP BETWEEN DRIVERS AND FISH METRIC GROUPS

The following metric groups and metrics were selected as potentially good indicators of changes in fish assemblages and habitat conditions.

A.5.1 Velocity-depth classes

This metric group is assessed based on a change in the "commonness" of the velocity-depth classes compared to the reference condition, and the response of the fish assemblage to the changes. This assessment is based on baseflow (low flow) conditions usually within the dry season (when surveys usually occur). However, apart from considering conditions during sampling, the general change based on driver information should be derived for all seasons.

A.5.1.1 Velocity-depth class changes

Information from the geomorphological (sediment movement) and hydrological (flow modifications) driver groups are used to do the assessment. These changes can be based on empirical information supplemented by derived changes to the fish assemblage or based on the changes to driver components that will be reflected by particular fish species responses:

- Commonness of fast-deep conditions
- Commonness of fast-shallow conditions
- Commonness of slow-deep conditions
- Commonness of slow-shallow conditions

These changes are rated according the following scheme:

- -5 = Extreme loss from reference (absent)
- -4 = Serious loss from reference
- -3 = Large loss from reference
- -2 = Moderate loss from reference
- -1 = Small loss from reference
- 0 = No change from reference
- 1 = Small increase from reference
- 2 = Moderate increase from reference
- 3 = Large increase from reference
- 4 = Serious increase from reference
- 5 = Extreme increase from reference (completely dominant)

This assessment of the change of velocity-depth classes from the reference condition is used as a basis for the rating of changes in the fish assemblage However, these ratings are independent of the fish assemblage response, that is, the ratings are not factored into the fish response assessment in the FRAI model.

A.5.1.2 Fish assemblage changes

To provide a reasonable level of response interpretation, only fish species with a high or very high preference for the respective velocity-depth groups are considered.

Based on empirical fish data, as well as derived data (based on velocity-depth class changes), and with reference to velocity-depth class preferences of the fish species, how did the following change?

- Response of species with high to very high preference for fast-deep conditions
- Response of species with high to very high preference for fast-shallow conditions
- Response of species with high to very high preference for slow-deep conditions
- Response of species with high to very high preference for slow-shallow conditions

The rating system follows the approach indicated under the velocity-depth class metric group.

A.5.2 Cover

Species have particular requirements for habitat conditions that provide cover from adverse environmental conditions and predation. A modification in habitat may be related to flow changes (increase or decrease) or physical modification such as bank collapse and sedimentation.

A.5.2.1 Cover class changes

Information from the geomorphological and hydrological components and metrics, as well as the riparian vegetation, is used to do the assessment. These changes can be based on empirical information supplemented by derived changes to the fish assemblage, or based on the changes to driver components and metrics that will be reflected by particular fish species responses:

- Commonness of overhanging vegetation
- Commonness of undercut banks and root wads
- Commonness of substrate types that can serve as cover
- Commonness of instream vegetation
- Commonness of sufficient water column depth that can serve as cover

The rating system follows the approach indicated under the velocity-depth class metric group.

This assessment of the change of cover classes from the reference condition is used as a basis for the rating of changes in the fish assemblage. However, these ratings are independent from the fish assemblage response, that is, the ratings are not factored into the fish response assessment in the FRAI model.

A.5.2.2 Fish assemblage changes

To provide a reasonable level of response interpretation, only fish species with a high or very high preference for the respective cover classes are considered.

- Response of species with a very high to high preference for overhanging vegetation. Reduction may indicate lowered water levels, bank erosion or physical destruction of overhanging vegetation.
- Response of species with a very high to high preference for undercut banks and root wads. Reduction may indicate lowered water levels, bank erosion and bank

collapse.

- Response of species with a high to very high preference for a particular substrate type. Reduction may indicate sedimentation (embedding of cobbles and gravel in riffles, for instance), or algal growth.
- Response of species with a high to very high preference for instream vegetation. Reduction may indicate lowered water levels or physical destruction of aquatic macrophytes.
- Response of species with a very high to high preference for the water column. Reduction of species may indicate lowered water levels or loss of depth due to sedimentation (in pools). Predation from aerial predators may be an important factor.

The rating system follows the approach indicated under the velocity-depth class metric group.

A.5.2.3 Flow modification

This metric group is interpreted based entirely on the level of requirement that various species (or life-stages of a species) have for flowing water. The aspects of the impact of flow modification on physical habitat attributes are considered under other metric groups such as cover and velocity-depth classes.

A.5.2.4 Changes in flow characteristics

Information from the hydrological driver group is used for the assessment. These changes can be based on empirical information supplemented by derived changes to the fish assemblage or based on the changes to driver components that will be reflected by particular fish species responses -

- Increase or decrease in no-flow conditions
- Increase or decrease in low-flow conditions
- Change in seasonality
- Increase or decrease in moderate events
- Increase or decrease in events (high flow, floods)

The rating system follows the approach indicated under the velocity-depth class metric group.

This assessment of the change of cover classes from the reference condition is used as a basis for the rating of changes in the fish assemblage However, these ratings are independent from the fish assemblage response, that is, the ratings are not factored into the fish response assessment in the FRAI model.

A.5.2.5 Fish assemblage changes

Fish response assessment is based on empirical information supplemented by derived changes to the fish assemblage, or based on hydrological driver changes that will be reflected by particular fish species responses.

- Response of species intolerant of no-flow conditions
- Response of species moderately intolerant of no-flow conditions
- Response of species moderately tolerant of no-flow conditions
- Response of species tolerant of no-flow conditions

Rating of these responses follows the approach indicated under velocity-depth class metric group.

A.5.3 Response to physico-chemical conditions: health and condition

Health and condition of species are a reflection of the well-being of fish. Adverse environmental conditions (caused by decrease in food availability, modified physico-chemical conditions, decrease in preferred habitat, for instance, all of which may be related to flow alteration) may result in physiological stress conditions that impact on the immune system of species, resulting in deterioration of health and condition. For the FRAI, modified physico-chemical conditions are the primary consideration.

A.5.3.1 Changes in physico-chemical conditions

The following physico-chemical driver information is used to assess potential responses of the fish assemblage:

- pH
- Salts
- Nutrients
- Temperature
- Turbidity
- Oxygen
- Toxics

In the absence of a specific physico-chemical assessment, ratings are done according to:

- 0 = No change from reference
- 1 = Small change from reference
- 2 = Moderate change from reference
- 3 = Large change from reference
- 4 = Serious change from reference
- 5 = Extreme change from reference

A.5.3.2 Fish assemblage changes

Direct observation of health assessment is based on observations on deformities, fin erosion, lesions and tumours (DELT) and consideration of driver status. Where such information is limited, information on the physico-chemical driver group should be used to derive the expected response of the species expected under reference conditions. For the purpose of the FRAI determination, it is accepted that all species should be in a healthy condition (reference = 0) and that deviation from this could only be negative.

Health and condition responses are considered in terms of four metrics -

- Response of species intolerant of modified physico-chemical conditions
- Response of species moderately intolerant of modified physico-chemical conditions
- Response of species moderately tolerant of modified physico-chemical conditions
- Response of species tolerant of modified physico-chemical conditions

Rating of responses is as for the changes in physico-chemical conditions.

A.5.4 Migration

The severity of the impact of obstruction of fish movement on the distribution, abundance and survival of a fish species in the particular river forms the basis of the assessment. Migration can be related to breeding, feeding and survival life-history strategies.

A.5.4.1 Changes in population connectivity

Any modification that results in the fragmentation of fish populations is considered.

The presence and extent of the following are considered in evaluating the impact on and response of migratory species:

- Weirs and causeways
- Impoundments
- Physico-chemical barriers
- Flow modifications

These changes are rated according the following -

- 0 = None, or no potential impact
- 1 = Small; limited with small potential impact on movement.
- 2 = Moderate; notable and with potential impact on movement.
- 3 = Large; clear potential impact on movement.
- 4 = Serious; clear and serious potential impact on movement.
- 5 = Extreme; clear and critical potential impact on the movement.

This assessment of the potential loss of connectivity is used as a basis for the rating of changes in the fish assemblage However, these ratings are independent from the fish assemblage response, that is, the ratings are not factored into the fish response assessment in the FRAI model.

A.5.4.2 Fish assemblage changes

Distribution and abundance responses of migratory species are based on empirical information or can be derived from the potential impact of various geomorphological, hydrological and physico-chemical changes. Three broad levels of migratory requirements form the basis of the assessment :

- Response in terms of distribution/abundance of species with catchment scale movements
- Response in terms of distribution/abundance of species with requirement for movement between reaches or fish habitat segments
- Response in terms of distribution/abundance of species with requirement for movement within reach or fish habitat segment

Ratings are done according to -

- 0 = No change from reference
- 1 = Small change from reference; only a small part of the stream network or reach is inaccessible
- 2 = Moderate change from reference; moderate part of the stream network or reach is inaccessible
- 3 = Large change from reference; a large part of the stream network or reach is inaccessible
- 4 = Serious change from reference; an extensive part of the stream network or reach is inaccessible
- 5 = Extreme change from reference; the entire stream network or reach is inaccessible

A.5.5 Introduced species

The relevance of this metric group is that introduced species may have a dominant impact on the native fish assemblage, while the physical drivers may actually be in a close to reference condition. In this sense, the introduced species metric can be seen as a modifying determinant that does not necessarily impact the fish assemblage through habitat changes as the other metric groups do.

Introduced fish species can have a severe effect on the habitat structure (indirectly influencing the natural fish assemblage) and the fish assemblage structure itself through predation. The potential impact of the species is based on the characteristics of the species (that is, its size, trophic preferences and feeding methods). The distribution (and indirectly the abundance) is considered to be another aspect that will determine the impact of an introduced species (that is, whether it has highly invasive properties and is generally tolerant to environmental conditions). The number of introduced species under each metric should also be considered.

The attributes of the native species present should be considered in terms of how vulnerable they are to the impact of introduced species. The habitat characteristics in the river delineation, in combination with the requirements of the introduced species, can also be used to derive the impact of such species on the native ones. For the purpose of the FRAI determination, no introduced species should be present (reference = 0), and any deviation from this can only be regarded as resulting in a decrease in the frequency of occurrence of native species vulnerable to introduced species' impact..

Two groups of introduced species are considered in terms of competition (predation and competition for resources) and habitat modifiying impacts -

- The potential competition impact of introduced (including predators) species.
- How widespread (frequency of occurrence) are introduced competitors
- The potential impact of introduced habitat modifying species.
- How widespread (frequency of occurrence) are habitat modifying species.

A.5.5.1 Impact guidelines

- Predaceous species / habitat modifying species with a critical impact on native species = 5
- Predaceous species / habitat modifying species with a serious impact on native species = 3-4
- Predaceous species / habitat modifying species with a moderate impact on native species = 2-1
- Predaceous species / habitat modifying species with no impact on native species, or are absent completely = 0

A.5.5.2 Distribution guidelines

- 0 = absent
- 1 = present at very few sites (<10%)
- 2 = present at few sites (>10-25%)
- 3 = present at about >25-50 % of sites
- 4 = present at most sites (>50-75%)
- 5 = present at almost all sites (>75%)

A.6 RATING AND WEIGHTING OF METRICS

A.6.1 Rating

The principle of the approach was that the frequency of occurrence of a species in combination with its intolerance or preference, provide information on the change of the fish assemblage from the reference condition. For this calculation the reference frequency of occurrence must be estimated and the present (or observed) frequency of occurrence determined or derived from habitat conditions.

For the velocity-depth, cover, flow modification and physico-chemical metric groups the following procedure was followed to calculate ratings and weights for each metric:

Rt= ? (RFr X Int)/(25))/? (OFr X Int)/25

Where:

Rts= rating for metric
RFr=reference frequency of occurrence for each species
I nt=Intolerance rating for each species (or preference rating)

The result of this calculation was transformed to a value between -5 to 5

A.6.2 Weighting

This was determined by firstly proportioning the rating of a metric according to the number species in that metric:

Mp=Rt/Nsp

Where:

Mp=Metric proportion
Nsp=number of species

This was done for each metric in a group. The metric with the highest proportion was used as the basis to proportion the other metrics. This means that the metric with the highest proportion would be the one where the metric rating was fully applied in the assessment (100% of the rating), and the ratings of the rest proportionally less.

A.7 DETERMINING THE WEIGHT OF METRIC GROUPS

Metric group weight are determined a ccording to a Analytical Hierarchical Procedure (AHP)(Saaty 1980; US Army Corps of Engineers 1980). The purpose of this approach is to provide a reasonably objective way to determine the weights of metric groups. An AHP approach is followed where the metric groups are compared pairwise on a 0 – 10 scale with 0.5 intervals. Metric group weights are determined in the FRAI model sheet: METRIC GROUP WEIGHTS.

The objective is to determine the weight of various metric groups as it relates to the natural attributes and requirements of the reference fish assemblage. Introduced species are not a natural attribute or requirement is considered in a different (negative) context.

The basic question is:

Considering

- The natural characteristics of the fish assemblage and its habitat, and
- when comparing a pair of fish metric groups,

which member in the pair would contribute most to a decline or improvement in the fish assemblage integrity if it was to change for whatever reason?

Approach:

The pair with the highest importance in this situation would then receive the highest rating out of 10 with the residue being awarded to the member with the lower contribution. If both members are equally important, both would receive a rating of 5

Considerations:

- Metric groups: VEL_DEPTH, COVER, FLOW_MOD, PHYSCHEM, the number of species in each metric group, their intolerances as well as habitat characteristics should be taken as the basis of comparison between members of a pair.
- Metric group: MIGRATION, the number of species with various migration requirements should be considered.
- Metric group: INTRO, the characteristics and distribution of the introduced species should be considered together with the vulnerability of the indigenous species. This refers only to species that have already been introduced to system and not to species that can potentially be introduced.

A.8 FORMULATION OF THE FRAI

Metric groups (Mg):

1) For velocity-depth, flow modification, cover, physico-chemical and migration metric groups:

Mg= 100 - ((Obs? Metric X w)/(Ref ? Metric X w)*100)

Where:

Mg= Relative condition of metric group (%)
Obs=Observed rating for metric
Ref=Reference rating for metric
w = Weight of metric

2) For introduced species metric group:

Pig= ((Obs? metric x w)/(Max? metric x w)*100

Where;

Pig=Potential impact of introduced species group(%)

Obs= Rated potential impact of species observed to be present
Max=Maximum potential impact of species present
w= Weight of metric

Fish Response Assessment Index (FRAI):

FRAI = (? Mg X w) – (Pig X wi)

Where:

FRAI= Relative integrity of fish assemblage (%)
Mg = Relative condition of metric group
w = Weight of metric group
Pig = Potential impact of introduced species metric group(%)
wi = Weight of Pig metric group in terms of vulnerability of native fish assemblage.

B APPENDIX B: FISH DATA SHEETS

Table B.1 Site information (adapted from Dallas 2005)

Assessor Name(s)							
Organisation					Date	/ /	
Site information - assessed at the site							
RHP Site Code			Project Site Number				
River			Tributary of				
Farm Name:			Farm Reg. Code:				
Latitude and longitude co-ordinates:							
Degrees-minutes-seconds		or Decimal degrees		or Degrees & decimal minutes			
S ° ' . "		S . °		S ° . '		Cape datum Clarke	
E 0 ° ' . "		E 0 . °		E 0 ° . '		WGS-84 datum HBH94	
Site Description							
Map Reference (1: 50 000)			Site Length (m)		Altitude (m)		
Longitudinal Zone	Source zone	Mountain headwater stream	Mountain stream	Transitional	Upper foothill	Lower foothill	Lowland river
Rejuvenated cascades (gorge)	Rejuven-ated foothill	Upland floodplain	Other:				
Associated Systems:	Wetland	Estuary	Other:		Distance:		
Additional Comments:							

Desktop / spatial information – data used for classifying a site and subsequent querying of data								
Political Region				Water Management Area				
Ecoregion I				Ecoregion II				
Secondary Catchment				Quaternary Catchment				
Water Chemistry Management Region								
Vegetation Type				Geological Type				
Contour Range (m): From:			to:					
Source Distance (km)				Stream Order				
Rainfall Region	Summer	Winter	Aseasonal	Other:				
DWAF Gauging Station	Yes	No	Code :		Distance Upstream		Or Downstream	

Table B.2 Velocity-depth classes sampled and effort.

Indicate which velocity-depth classes were sampled. Where the mosaic of velocity-depth classes makes it difficult or impossible to sample classes separately (e.g. combinations of fast-deep and fast-shallow classes), the dominant velocity-depth class should be used as the unit of reference for sampling effort, but the presence of other velocity-depth classes should also be indicated.

Sampling effort	Slow deep (SD)	Slow shallow (SS)	Fast deep (FD)	Fast shallow (FS)
Dominant velocity-depth class				
Electro shocker (min)				
Small seine (mesh size, length, depth, efforts)				
Large seine (mesh size, length, depth, efforts)				
Cast net (dimensions, efforts)				
Gill nets (mesh size, length, time)				

Remarks:

Table B.3 Fish caught (Indicate where velocity-depth combined)

Habitat (velocity-depth class(es)	
Sampling method:	
Species	**Number (J = juvenile, A = abnormality)**

C APPENDIX C: FRAI SPREADSHEETS

SURVEY DATA

include information on site sampled

SITE NUMBER:	**LATITUDE**	**LONGITUDE**	**QUAT**	**MAJOR RIVERS**	**TRIBUTARY**	**ECOREGION**	**GEOMORPH ZONE**	**ALTITUDE (m)**
DATE		TIME:						
WIDTH:		GENERAL FLOW:						

FISH VELOCITY-DEPTH CLASSES AND COVER PRESENT AT SITE

(Abundance: 0=absent; 1=rare; 2=sparse; 3=moderate; 4=abundant; 5=very abundant)

SLOW DEEP:	SLOW SHALLOW:	FAST DEEP:	FAST SHALLOW:
Overhanging vegetation:	Overhanging vegetation:	Overhanging vegetation:	Overhanging vegetation:
Undercut banks & root wads:	Undercut banks & root wads:	Undercut banks & root wads:	Undercut banks & root wads:
Substrate:	Substrate:	Substrate:	Substrate:
Aquatic macrophytes:	Aquatic macrophytes:	Aquatic macrophytes:	Aquatic macrophytes:
Water Column:	Water Column:	Water Column:	Water Column:
Remarks:	Remarks:	Remarks:	Remarks:

HABITATS SAMPLED AND EFFORT

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALL OW
Electro schocker (min)				
Small seine (mesh size, length, depth, efforts)				
Large seine (mesh size, length, depth, efforts)				
Cast net (dimensions, efforts)				
Gill nets (mesh size, length, time)				

		NUMBERS		
SPECIES SAMPLED	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST DEEP

SCIENTIFIC NAMES

FRESHWATER SPECIES SCIENTIFIC NAME, ABBREVIATION AND COMMON NAME. SHADED BLOCKS INDICATE SPECIES FOR WHICH NO RATINGS WERE DONE (information provided by Skelton 1997)
Light grey shading: Exotic and indigenous species for which ratings do exist
(ex) = exotic

ABBREV	SCIENTIFIC NAME	ENGLISH COMMON NAME
AAEN	*AWAOUS AENEOFUSCUS* (PETERS 1852)	FRESHWATER GOBY (M)
ABAR	*AUSTROGLANIS BARNARDI* (SKELTON, 1981)	BARNARD'S ROCK CATFISH
ABER	*ACANTHOPAGRUS BERDA* (FORSSKÅL, 1775)	RIVERBREAM (MS)
ABIC	*ANGUILLA BICOLOR BICOLOR* MCCLELLAND, 1844	SHORTFIN EEL
ABRE	*ATHERINA BREVICEPS* VALENCIENNES, 1835	CAPE SILVERSIDE
AGIL	*AUSTROGLANIS GILLI* (BARNARD, 1943)	CLANWILLIAM ROCK-CATFISH
AJOH	*APLOCHEILICHTHYS JOHNSTONI* (GÜNTHER, 1893)	JOHNSTON'S TOPMINNOW
AKAT	*APLOCHEILICHTHYS KATANGAE* (BOULENGER, 1912)	STRIPED TOPMINNOW
ALAB	*ANGUILLA BENGALENSIS LABIATA* PETERS, 1852	AFRICAN MOTTLED EEL
AMAR	*ANGUILLA MARMORATA* QUOY & GAIMARD 1824	GIANT MOTTLED EEL
AMOS	*ANGUILLA MOSSAMBICA* PETERS 1852	LONGFIN EEL
AMYA	*APLOCHEILICHTHYS MYAPOSAE* (BOULENGER, 1908)	NATAL TOPMINNOW
ANAT	*AMPHILIUS NATALENSIS* BOULENGER, 1917	NATAL MOUNTAIN CATFISH
ASCL	*AUSTROGLANIS SCLATERI* (BOULENGER, 1901)	ROCK-CATFISH
AURA	*AMPHILIUS URANOSCOPUS* (PFEFFER, 1889)	STARGAZER (MOUNTAIN CATFISH)
BAEN	*LABEOBARBUS AENEUS* (BURCHELL, 1822)	SMALLMOUTH YELLOWFISH
BFRI	*BARBUS AFROHAMILTONI* CRASS, 1960	HAMILTON'S BARB
BAMA	*BARBUS AMATOLICUS* SKELTON, 1990	AMATOLA BARB
BAND	*BARBUS ANDREWI* BARNARD, 1937	WHITEFISH
BANN	*BARBUS ANNECTENS* GILCHRIST & THOMPSON, 1917	BROADSTRIPED BARB
BANO	*BARBUS ANOPLUS* WEBER, 1897	CHUBBYHEAD BARB
BARG	*BARBUS ARGENTEUS* GÜNTHER, 1868	ROSEFIN BARB
BBIF	*BARBUS BIFRENATUS* FOWLER, 1935	HYPHEN BARB
BBRI	*BARBUS BREVIPINNIS* JUBB, 1966	SHORTFIN BARB
BCAL	*BARBUS CALIDUS* BARNARD, 1938	CLANWILLIAM REDFIN
BCAP	*BARBUS CAPENSIS* SMITH, 1841	CLANWILLIAM YELLOWFISH
BERU	*BARBUS ERUBESCENS* SKELTON, 1974	TWEE RIVER REDFIN
BEUT	*BARBUS EUTAENIA* BOULENGER, 1904	ORANGEFIN BARB
BGUR	*BARBUS GURNEYI* GÜNTHER, 1868	REDTAIL BARB
BHOS	*BARBUS HOSPES* BARNARD, 1938	NAMAQUA BARB
BIMB	*BRYCINUS IMBERI* (PETERS, 1852)	IMBERI
BKIM	*LABEOBARBUS KIMBERLEYENSIS* GILCHRIST & THOMPSON, 1913	LARGEMOUTH YELLOWFISH
BLAT	*BRYCINUS LATERALIS* (BOULENGER, 1900)	STRIPED ROBBER
BLIN	*BARBUS LINEOMACULATUS* BOULENGER, 1903	LINE-SPOTTED BARB
BMAR	*LABEOBARBUS MAREQUENSIS* SMITH, 1841	LARGESCALE YELLOWFISH
BMAT	*BARBUS MATTOZI* GUIMARAES, 1884	PAPERMOUTH
BMOT	*BARBUS MOTEBENSIS* STEINDACHNER, 1894	MARICO BARB
BNAT	*BARBUS NATALENSIS* CASTELNAU, 1861	SCALY
BNEE	*BARBUS NEEFI* GREENWOOD, 1962	SIDESPOT BARB
BPAL	*BARBUS PALLIDUS* SMITH, 1841	GOLDIE BARB
BPAU	*BARBUS PALUDINOSUS* PETERS, 1852	STRAIGHTFIN BARB
BPOL	*LABEOBARBUS POLYLEPIS* BOULENGER, 1907	SMALLSCALE YELLOWFISH

BRAD	*BARBUS RADIATUS* PETERS, 1853	BEIRA BARB
BSER	*BARBUS SERRA* PETERS, 1864	SAWFIN
BTOP	*BARBUS TOPPINI* BOULENGER, 1916	
BTRE	*BARBUS TREURENSIS* GROENEWALD, 1958	TREUR RIVER BARB
BTRI	*BARBUS TRIMACULATUS* PETERS, 1852	THREESPOT BARB
BUNI	*BARBUS UNITAENIATUS GÜNTHER, 1866*	LONGBEARD BARB
BTRV	*BARBUS TREVELYANI* GÜNTHER, 1877	
BVIV	*BARBUS VIVIPARUS* WEBER, 1897	BOWSTRIPE BARB
CANO	*CHILOGLANIS ANOTERUS* CRASS, 1960	PENNANT TAIL SUCKERMOUTH (OR ROCK CATLET)
CAUR	*CARASSIUS AURATUS* (LINNAEUS, 1758)	GOLDFISH (EX)
CBIF	*CHILOGLANIS BIFURCUS* JUBB & LE ROUX, 1969	INCOMATI SUCKERMOUTH (OR ROCK CATLET)
CBRE	*CHETIA BREVIS* JUBB, 1968	ORANGE-FRINGED LARGEMOUTH
CCAR	*CYPRINUS CARPIO* LINNAEUS, 1758	CARP (EX)
CEMA	*CHILOGLANIS EMARGINATUS* JUBB & LE ROUX, 1969	PONGOLO SUCKERMOUTH (OR ROCK CATLET)
CFLA	*CHETIA FLAVIVENTRIS* TREWAVAS, 1961	CANARY KURPER
CGAR	*CLARIAS GARIEPINUS* (BURCHELL, 1822)	SHARPTOOTH CATFISH
CIDE	*CTENOPHARYNGODON IDELLA* (VALENCIENNES, 1844)	GRASS CARP (EX)
CMUL	*CTENOPOMA MULTISPINE* PETERS, 1844	MANYSPINED CLIMBING PERCH
CPAR	*CHILOGLANIS PARATUS* CRASS, 1960	SAWFIN SUCKERMOUTH (OR ROCK CATLET)
CPRE	*CHILOGLANIS PRETORIAE* VAN DER HORST, 1931	SHORTSPINE SUCKERMOUTH (OR ROCK CATLET)
CSWI	*CHILOGLANIS SWIERSTRAI* VAN DER HORST, 1931	LOWVELD SUCKERMOUTH (OR ROCK CATLET)
CTHE	*CLARIAS THEODORAE* WEBER, 1897	SNAKE CATFISH
GAES	*GILCHRISTELLA AESTUARIA* (GILCHRIST, 1913)	ESTUARINE ROUND-HERRING
GAFF	*GAMBUSIA AFFINIS* (BAIRD & GIRARD, 1853)	MOSQUITOFISH (EX)
GCAL	*GLOSSOGOBIUS CALLIDUS* SMITH, 1937	RIVER GOBY (M)
GGIU	*GLOSSOGOBIUS GIURIS* (HAMILTON-BUCHANAN, 1822)	TANK GOBY (M)
GZEB	*GALAXIAS ZEBRATUS* CASTELNAU, 1861	CAPE GALAXIAS
HANS	*HIPPOPOTAMYRUS ANSORGII* (BOULENGER,1905)	SLENDER STONEBASHER
HCAP	*HYPORHAMPHUS CAPENSIS* (THOMINOT, 1886)	CAPE HALFBEAK (MS)
HMOL	*HYPOPHTHALMICHTHYS MOLITRIX* (VALENCIENNES, 1844)	SILVER CARP (EX)
HVIT	*HYDROCYNUS VITTATUS* CASTELNAU, 1861	TIGERFISH
KAUR	*KNERIA AURICULATA* (PELLEGRIN, 1905)	SOUTHERN KNERIA
LCAP	*LABEO CAPENSIS* (SMITH, 1841)	ORANGE RIVER LABEO
LCON	*LABEO CONGORO* PETERS, 1852	PURPLE LABEO
LCYL	*LABEO CYLINDRICUS* PETERS, 1852	REDEYE LABEO
LMAC	*LEPOMIS MACROCHIRUS* RAFINESQUE, 1819	BLUEGILL SUNFISH (EX)
LMCR	*LIZA MACROLEPIS* (SMITH, 1846)	LARGE-SCALE MULLET (MS)
LMOL	*LABEO MOLYBDINUS* DU PLESSIS, 1963	LEADEN LABEO
LRIC	*LIZA RICHARDSONII* (SMITH, 1846)	SOUTHERN MULLET (MS)
LROS	*LABEO ROSAE* STEINDACHNER, 1894 (*LABEO ALTEVILIS*)	REDNOSE LABEO
LRUB	*LABEO RUBROMACULATUS* GILCHRIST & THOMPSON, 1913	TUGELA LABEO
LRUD	*LABEO RUDDI* BOULENGER, 1907	SILVER LABEO
LSEE	*LABEO SEEBERI* GILCHRIST & THOMPSON, 1911	CLANWILLIAM SANDFISH
LUMB	*LABEO UMBRATUS* (SMITH, 1841)	MOGGEL
MACU	*MICRALESTES ACUTIDENS* (PETERS, 1852)	SILVER ROBBER

MARG	*MONODACTYLUS ARGENTEUS* (LINNAEUS, 1758)	NATAL MOONY (MS)
MBRA	*MICROPHIS BRACHYURUS* BLEEKER, 1853	OPOSSUM PIPEFISH (M)
MBRE	*MESOBOLA BREVIANALIS* (BOULENGER, 1908)	RIVER SARDINE
MCAP	*MYXUS CAPENSIS* (VALENCIENNES, 1836)	FRESHWATER MULLET (M)
MCEP	*MUGIL CEPHALUS* LINNAEUS, 1758	FLATHEAD MULLET (M)
MCYP	*MEGALOPS CYPRINOIDES* (BROUSSONET, 1782)	OXEYE TARPON
MDOL	*MICROPTERUS DOLOMIEU* LACEPÈDE, 1802	SMALLMOUTH BASS (EX)
MFAL	*MONODACTYLUS FALCIFORMIS* LACEPÈDE, 1801	CAPE MOONY (MS)
MFLU	*MICROPHIS FLUVIATILIS* (PETERS, 1852)	FRESHWATER PIPEFISH (M)
MMAC	*MARCUSENIUS MACROLEPIDOTUS* (PETERS, 1852)	BULLDOG
MPUN	*MICROPTERUS PUNCTULATUS* (RAFINESQUE, 1819)	SPOTTED BASS (EX)
MSAL	*MICROPTERUS SALMOIDES* (LACEPÈDE, 1802)	LARGEMOUTH BASS (EX)
NORT	*NOTHOBRANCHIUS ORTHONOTUS* (PETERS, 1844)	SPOTTED KILLIFISH
NRAC	*NOTHOBRANCHIUS RACHOVII* AHL, 1926	RAINBOW KILLIFISH
OAUR	*OREOCHROMIS AUREUS* (STEINDACHNER, 1864)	ISRAELI TILAPIA (EX)
OMAC	*OREOCHROMIS (NYASALAPIA) MACROCHIR* (BOULENGER, 1912)	GREENHEAD TILAPIA
OMOS	*OREOCHROMIS MOSSAMBICUS* (PETERS, 1852)	MOZAMBIQUE TILAPIA
OMYK	*ONCORHYNCHUS MYKISS* (WALBAUM, 1792)	RAINBOW TROUT (EX)
ONIL	*OREOCHROMIS NILOTICUS (LINNAEUS, 1758)*	NILE TILAPIA (EX)
OPER	*OPSARIDIUM PERINGUEYI* (GILCHRIST & THOMPSON, 1913)	SOUTHERN BARRED MINNOW
OPLA	*OREOCHROMIS PLACIDUS* (TREWAVAS, 1941)	BLACK TILAPIA
PAFE	*PSEUDOBARBUS AFER* (PETERS, 1864)	EASTERN CAPE REDFIN
PAMP	*PROTOPTERUS AMPHIBIUS* (PETERS, 1844)	EAST COAST LUNGFISH
PANN	*PROTOPTERUS ANNECTENS BRIENI* POLL,1961	LUNGFISH
PASP	*PSEUDOBARBUS ASPER* (BOULENGER, 1911)	SMALLSCALE REDFIN
PBUG	*PSEUDOBARBUS BURGI* (BOULENGER, 1911)	BERG RIVER REDFIN
PBUR	*PSEUDOBARBUS BURCHELLI* SMITH, 1841	BURCHELL'S REDFIN
PCAT	*PETROCEPHALUS WESSELSI* KRAMER & VAN DER BANK, 2000	SOUTHERN CHURCHILL
PFLU	*PERCA FLUVIATILIS* LINNAEUS, 1758	EUROPEAN PERCH (EX)
PPHI	*PSEUDOCRENILABRUS PHILANDER* (WEBER, 1897)	SOUTHERN MOUTHBROODER
PPHL	*PSEUDOBARBUS PHLEGETHON* (BARNARD, 1938)	FIERY REDFIN
PQUA	*PSEUDOBARBUS QUATHLAMBAE* (BARNARD, 1938)	DRAKENSBERG MINNOW
PRET	*POECILIA RETICULATA* PETERS, 1859	GUPPY (EX)
PTEN	*PSEUDOBARBUS TENUIS* (BARNARD, 1938)	SLENDER REDFIN
RDEW	*REDIGOBIUS DEWAALI* (WEBER, 1897)	CHECKED GOBY (M)
SBAI	*SANDELIA BAINSII* CASTELNAU, 1861	EASTERN CAPE ROCKY
SCAP	*SANDELIA CAPENSIS* (CUVIER, 1831)	CAPE KURPER
SFON	*SALVELINUS FONTINALIS* (MITCHILL, 1815)	BROOK CHARR (EX)
SINT	*SCHILBE INTERMEDIUS* RÜPPELL, 1832	SILVER CATFISH
SMER	*SERRANOCHROMIS MERIDIANUS* JUBB, 1967	LOWVELD LARGEMOUTH
SSIB	*SILHOUETTEA SIBAYI* FARQUHARSON, 1970	SIBAYI GOBY (M)
STRU	*SALMO TRUTTA* LINNAEUS, 1758	BROWN TROUT (EX)
SZAM	*SYNODONTIS ZAMBEZENSIS* PETERS, 1852	BROWN SQUEAKER
TREN	*TILAPIA RENDALLI* (BOULENGER, 1896)	REDBREAST TILAPIA
TSPA	*TILAPIA SPARRMANII* SMITH, 1840	BANDED TILAPIA
TTIN	*TINCA TINCA* (LINNAEUS, 1758)	TENCH (EX)
VNEL	*VARICORHINUS NELSPRUITENSIS* GILCHRIST & THOMPSON, 1911	INCOMATI CHISELMOUTH
XHEL	*XIPHOPHORUS HELLERI* HECKEL, 1848	SWORDTAIL (EX)

SPP INTOL PREF

		VELOCITY-DEPTH PREFERENCE				FLOW INTOLERANCE				COVER PREFERENCE					TOLERANCE: MODIFIED PHYSICO-CHEM				MIGRATION		
SPECIES EXPECTED: REFERENCE (NOT INTRODU SPP)	SCIENTIFIC NAMES	PREFERENCE: FD	PREFERENCE:FS	PREFERENCE:SD	PREFERENCE:SS	INTOLERANT: NO-FLOW (>4)	MODERATELY INTOLERANT: NO FLOW(>3-4)	MODERATELY TOLERANT: NO FLOW (>2-3)	TOLERANT: NO FLOW (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: MODIFIED VQ (>4)	MODERATELY INTOLERANT: MODIFIED VQ (>3-4)	MODERATELY TOLERANT (>2-3): MODIFIED VQ	TOLERANT: MODIFIED VQ (1-2)	5 -Species with requirement for catchment scale migrations 3 - Species with requirement for movement between reaches / fish habitat segments 1 - Species with requirement for movement within reaches / fish habitat segments	CONFIDENCE	Distance migrating (km)
AURA	AMPHILIUS URANOSCOPUS (PFEFFER, 1889)	4.60	4.60	FALSE	FALSE	4.80	FALSE	FALSE	FALSE	FALSE	FALSE	5.00	FALSE	FALSE	4.80	FALSE	FALSE	FALSE	1.00	3.00	Very local
AMOS	ANGUILLA MOSSAMBICA PETERS 1852	3.40	3.30	3.40	FALSE	FALSE	FALSE	2.80	FALSE	FALSE	4.10	4.90	FALSE	FALSE	FALSE	FALSE	2.50	FALSE	5.00	3.00	Up to watershed, >100km
AMAR	ANGUILLA MARMORATA QUOY & GAIMARD 1824	FALSE	FALSE	4.40	FALSE	FALSE	FALSE	2.80	FALSE	FALSE	3.90	4.20	FALSE	FALSE	FALSE	FALSE	2.50	FALSE	5.00	3.00	>100km (C1Up to 100 miles)
BANN	BARBUS ANNECTENS GILCHRIST & THOMPSON, 1917	FALSE	FALSE	5.00	FALSE	FALSE	FALSE	2.80	FALSE	FALSE	FALSE	FALSE	FALSE	4.70	FALSE	FALSE	3.00	FALSE	3.00	3.00	Far (50km?)
BBIF	BARBUS BIFRENATUS FOWLER, 1935	FALSE	FALSE	3.30	4.70	FALSE	FALSE	2.50	FALSE	4.40	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	3.00	FALSE	1.00	3.00	Local
BEUT	BARBUS EUTAENIA BOULENGER, 1904	4.30	4.70	FALSE	FALSE	4.60	FALSE	FALSE	FALSE	4.10	4.40	4.10	FALSE	FALSE	4.90	FALSE	FALSE	FALSE	3.00	3.00	Local
BMAR	LABEOBARBUS MAREQUENSIS SMITH, 1841	4.10	4.40	4.40	3.40	FALSE	3.20	FALSE	FALSE	FALSE	FALSE	4.50	FALSE	4.10	FALSE	FALSE	2.10	FALSE	3.00	3.00	Far (100km?)
BPAU	BARBUS PALUDINOSUS PETERS, 1852	FALSE	FALSE	3.90	3.90	FALSE	FALSE	2.30	FALSE	4.20	FALSE	FALSE	3.60	3.50	FALSE	FALSE	FALSE	1.80	3.00	3.00	V28km reported / specialist thinks much further (50km)
BTRI	BARBUS TRIMACULATUS PETERS, 1852	FALSE	FALSE	3.90	3.20	FALSE	FALSE	2.70	FALSE	3.90	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	1.80	3.00	3.00	Far (50+km?)
BUNI	BARBUS UNITAENIATUS GÜNTHER, 1866	FALSE	FALSE	5.00	4.30	FALSE	FALSE	2.30	FALSE	4.60	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	2.20	FALSE	3.00	3.00	Far (50km?)
BVIV	BARBUS VIVIPARUS WEBER, 1897	FALSE	FALSE	FALSE	4.80	FALSE	FALSE	2.30	FALSE	4.90	FALSE	FALSE	3.20	FALSE	FALSE	FALSE	3.00	FALSE	3.00	3.00	0-10km
CANO	CHILOGLANIS ANOTERUS CRASS, 1960	4.30	4.90	FALSE	FALSE	4.80	FALSE	FALSE	FALSE	FALSE	FALSE	4.90	FALSE	FALSE	4.70	FALSE	FALSE	FALSE	3.00	3.00	Local, 8km
CGAR	CLARIAS GARIEPINUS (BURCHELL, 1822)	FALSE	FALSE	4.30	3.40	FALSE	FALSE	FALSE	1.70	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	1.00	3.00	3.00	Long distances
CPAR	CHILOGLANIS PARATUS CRASS, 1960	4.20	4.90	FALSE	FALSE	FALSE	3.20	FALSE	FALSE	FALSE	FALSE	4.90	FALSE	FALSE	FALSE	3.10	FALSE	FALSE	3.00	3.00	Local
CSWI	CHILOGLANIS SWIERSTRAI VAN DER HORST, 1931	FALSE	4.70	FALSE	FALSE	4.80	FALSE	FALSE	FALSE	FALSE	FALSE	4.90	FALSE	FALSE	FALSE	3.30	FALSE	FALSE	3.00	3.00	Local
LCYL	LABEO CYLINDRICUS PETERS, 1852	3.40	4.80	FALSE	FALSE	FALSE	3.10	FALSE	FALSE	FALSE	FALSE	4.90	FALSE	FALSE	FALSE	3.10	FALSE	FALSE	3.00	3.00	Far (50km?)
LMOL	LABEO MOLYBDINUS DU PLESSIS, 1963	3.30	4.30	3.70	FALSE	FALSE	3.30	FALSE	FALSE	FALSE	FALSE	4.70	FALSE	FALSE	FALSE	3.20	FALSE	FALSE	3.00	3.00	Far (50km?)
MACU	MICRALESTES ACUTIDENS (PETERS, 1852)	FALSE	FALSE	4.30	4.30	FALSE	3.10	FALSE	FALSE	3.10	FALSE	FALSE	FALSE	4.00	FALSE	3.10	FALSE	FALSE	3.00	3.00	50 km

REF_OBS_SPP

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE	PES:OBSERVED & HABITAT DERIVED FREQUENCY OF OCCURRENCE

INTRO_ALIEN

INTRODUCED ALIEN PREDACEOUS SPP	PRESENCE=Y; ABSENCE=N	The potential impact of introduced competing /predaceous spp		INTRODUCED ALIEN HABITAT MODIFYING SPP	PRESENCE=Y; ABSENCE=N	The potential impact of introduced habitat modifying spp
GAFF				CAUR		
LMAC				CCAR		
MDOL				CIDE		
MPUN				HMOL		
MSAL				OAUR		
OMYK				OMAC		
ONIL				PRET		
PRET				TTIN		
SFON						
STRU						
XHEL						
PFLU						

VEL_DEPTH

CHANGE IN COMMONNESS OF VELOCITY-DEPTH CLASSES			
VELOCITY-DEPTH CLASSES METRICS WITH REFERENCE TO FLOW MODIFICATIONS AND CHANGES IN SEDIMENT MOVEMENT, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	UNDER REF COND	%WEIGHT	RATINGS
Commonness of FAST-DEEP conditions			
Commonness of FAST-SHALLOW conditions			
Commonness of SLOW-DEEP conditions			
Commonness of SLOW-SHALLOW conditions			
Absolute sum			
Absolute overall weighed % velocity-depth change			

AUTOMATED

CHANGES IN COMMONNESS OF SPECIES WITH HIGH TO VERY HIGH PREFERENCE FOR VELOCITY DEPTH CLASSES					
VELOCITY-DEPTH CLASSES METRICS BASED ON OBSERVED AND DERIVED DATA, AND WITH WITH REFERENCE TO VELOCITY-DEPTH CLASS PREFERENCES, HOW DID THE FOLLOWING CHANGE?	RANK	%WEIGHT	RATINGS	REF NUMBER OF SPP WITH PREFERENCE	PRESENT NUMBER OF SPP WITH PREFERENCE
Response of species with high to very high preference for FAST-DEEP conditions					
Response of species with high to very high preference for FAST-SHALLOW conditions					
Response of species with high to very high preference for SLOW-DEEPconditions					
Response of species with high to very high preference for SLOW-SHALLOW conditions					
Absolute sum					
Absolute overall weighed % assemblage change					

ADJUSTED

VELOCITY-DEPTH CLASSES METRICS BASED ON OBSERVED AND DERIVED DATA, AND WITH WITH REFERENCE TO VELOCITY-DEPTH CLASS PREFERENCES, HOW DID THE FOLLOWING CHANGE?	RANK	%WEIGHT	RATINGS
Response of species with high to very high preference for FAST-DEEP conditions			
Response of species with high to very high preference for FAST-SHALLOW conditions			
Response of species with high to very high preference for SLOW-DEEPconditions			
Response of species with high to very high preference for SLOW-SHALLOW conditions			
Absolute sum			
Absolute overall weighed % assemblage change			

COVER

CHANGE IN COMMONNESS OF FISH COVER FEATURES			
COVER METRICS: CHANGES IN FISH COVER FEATURES IN COMPARISON TO THE REFERENCE CONDITION	**COMMONNESS ORDER UNDER REF COND**	**%WEIGHT**	**RATINGS**
Commonness of overhanging vegetation			
Commonness of undercut banks and root wads			
Commonness of substrate types that can serve as cover			
Commonness of instream vegetation			
Commonness of sufficient water column depth that can serve as cover			
Absolute sum			
Absolute overall weighed % velocity-depth change			

AUTOMATED

CHANGE IN COMMONNESS OF SPECIES WITH PREFERENCE FOR SPECIFIC COVER FEATURES					
COVER METRICS: WITH REFERENCE TO CHANGES IN FISH COVER FEATURES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	**RANK**	**%WEIGHT**	**RATINGS**	**REF NUMBER OF SPP WITH PREFERENCE**	**PRESENT NUMBER OF SPP WITH PREFERENCE**
Response of species with a very high to high preference for overhanging vegetation					
Response of species with a very high to high preference for undercut banks and root wads					
Response of species with a high to very high preference for a particular substrate type					
Response of species with a high to very high preference for instream vegetation					
Response of species with a very high to high preference for the water column					
Absolute sum	0				
Absolute overall % assemblage change			**#DIV/0!**		

ADJUSTED

CHANGE IN COMMONNESS OF SPECIES WITH PREFERENCE FOR SPECIFIC COVER FEATURE			
COVER METRICS: WITH REFERENCE TO CHANGES IN FISH COVER FEATURES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	**RANK**	**%WEIGHT**	**RATINGS**
Response of species with a very high to high preference for overhanging vegetation			
Response of species with a very high to high preference for undercut banks and root wads			
Response of species with a high to very high preference for a particular substrate type			
Response of species with a high to very high preference for instream vegetation			
Response of species with a very high to high preference for the water column			
Absolute sum			
Absolute overall % assemblage change			

FLOW_MOD

FLOW MODIFICATIONS			
<u>FLOW MODIFICATION METRICS:</u> **WHAT IS THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE? (CARRIED OVER FROM DRIVER ASSESSMENT)**	**RANK**	**%WEIGHT**	**RATINGS**
Increase or decrease in low -flow conditions			
Increase or decrease in zero-flow conditions			
Change in seasonality			
Increase or decrease in moderate events			
Increase or decrease in events (high flow, floods)			
Absolute sum			
Absolute overall weighed % change in flow metrics			
AUTOMATED			

<u>FLOW MODIFICATION METRICS:</u> **IMPACT ON SPECIES WITH DIFFERENT LEVELS OF FLOW DEPENDANCE**					
<u>FLOW DEPENDANCE METRICS:</u> **BASED ON OBSERVED AND DERIVED DATA, AND WITH WITH REFERENCE FLOW DEPENDANCE, HOW DID THE FOLLOWING CHANGE?**	**RANK**	**%WEIGHT**	**RATINGS**	**REF NUMBER OF SPP WITH PREFERENCE**	**PRESENT NUMBER OF SPP WITH PREFERENCE**
Response of species intolerant of no-flow conditions					
Response of species moderately intolerant of no-flow conditions					
Response of species moderately tolerant of no-flow conditions					
Response of species tolerant of no-flow conditions					
Absolute sum					
Absolute overall % assemblage change					
ADJUSTED					

<u>FLOW MODIFICATION METRICS:</u> **IMPACT ON SPECIES WITH DIFFERENT LEVELS OF FLOW DEPENDANCE**			
<u>FLOW DEPENDANCE METRICS:</u> **BASED ON OBSERVED AND DERIVED DATA, AND WITH WITH REFERENCE FLOW DEPENDANCE, HOW DID THE FOLLOWING CHANGE?**	**RANK**	**%WEIGHT**	**RATINGS**
Response of species intolerant of no-flow conditions			
Response of species moderately intolerant of no-flow conditions			
Response of species moderately tolerant of no-flow conditions			
Response of species tolerant of no-flow conditions			
Absolute sum			
Absolute overall % assemblage change			

PHYSCHEM

PHYSICO-CHEMICAL CONDITIONS			
PHYSICO-CHEMICAL METRICS: WHAT IS THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE? (CARRIED OVER FROM PHYSICO-CHEMICAL DRIVER ASSESSMENT)	RANK	%WEIGHT	RATINGS
pH			
SALTS			
NUTRIENTS			
TEMPERATURE			
TURBIDITY			
OXYGEN			
TOXICS			
Absolute sum			
Absolute overall % change in physico-chemical conditions			

AUTOMATED

IMPACT ON SPECIES WITH DIFFERENT INTOLERANCE LEVELS TO CHANGE IN PHYSICO-CHEMICAL CONDITIONS					
PHYSICO-CHEMICAL METRICS: BASED ON OBSERVED AND DERIVED DATA, AND WITH REFERENCE TO INTOLERANCE TO MODIFIED PHYSICO-CHEMICAL CONDITIONS, HOW DID THE FOLLOWING RESPOND IN TERMS OF FISH HEALTH AND CONDITION?	RANK	%WEIGHT	RATINGS	REF NUMBER OF SPP WITH PREFERENCE	PRESENT NUMBER OF SPP WITH PREFERENCE
Response of species intolerant of modified physico-chemical conditions					
Response of species moderately intolerant of modified physico-chemical conditions					
Response of species moderately tolerant of modified physico-chemical conditions					
Response of species tolerant of modified physico-chemical conditions					
Absolute sum					
Absolute overall % impact on assemblage					

ADJUSTED

IMPACT ON SPECIES WITH DIFFERENT INTOLERANCE LEVELS TO CHANGE IN PHYSICO-CHEMICAL CONDITIONS			
PHYSICO-CHEMICAL METRICS: BASED ON OBSERVED AND DERIVED DATA, AND WITH REFERENCE TO INTOLERANCE TO MODIFIED PHYSICO-CHEMICAL CONDITIONS, HOW DID THE FOLLOWING RESPOND IN TERMS OF FISH HEALTH AND CONDITION?	RANK	%WEIGHT	RATINGS
Response of species intolerant of modified physico-chemical conditions			
Response of species moderately intolerant of modified physico-chemical conditions			
Response of species moderately tolerant of modified physico-chemical conditions			
Response of species tolerant of modified physico-chemical conditions			
Absolute sum	4		
Absolute overall % impact on assemblage			**32.3**

MIGRATION

CHANGES IN SYSTEM CONNECTIVITY	
<u>MIGRATION METRICS:</u> **WHAT IS THE EXTENT OF THE FOLLOWING**	**RATINGS**
Weirs and causeways	
Impoundments	
Physico-chemical barriers	
Flow modifications	

IMPACT ON SPECIES WITH DIFFERENT LEVELS OF MIGRATORY REQUIREMENTS					
<u>MIGRATION METRICS:</u> **BASED ON OBSERVED AND DERIVED DATA, AND WITH REFERENCE TO CHANGES IN SYSTEM CONNECTIVITY, HOW DID THE FOLLOWING CHANGE?**	**RANK**	**%WEIGHT**	**RATINGS**	**REF NUMBER OF SPP WITH PREFERENCE**	**PRESENT NUMBER OF SPP WITH PREFERENCE**
Response in terms of distribution/abundance of spp with catchment scale movements					
Response in terms of distribution/abundance of spp with requirement for movement between reaches or fish habitat segments					
Response in terms of distribution/abundance of spp with requirement for movement within reach or fish habitat segment					
Absolute sum	0				
Absolute overall % change in assemblage longitudinal continuity			**0.0**		

INTRO

INTRODUCED SPECIES IMPACT			
<u>INTRODUCED SPECIES METRICS:</u> **WITH REFERENCE TO THE TYPES OF INTRODUCED SPECIES, THE CHARACTERISTICS OF THE HABITAT AND THE NATIVE SPECIES, WHAT IS THE FOLLOWING OBSERVED OR EXPECTED TO BE?**	**RANK**	**%WEIGHT**	**RATINGS**
The impact/potential impact of introduced competing/predaceous spp?			
How widespread (frequency of occurrence) are introduced competing/predaceous spp?			
The impact/potential impact of introduced habitat modifying spp?			
How widespread (frequency of occurrence) are habitat modifying spp?			
Absolute sum	0		
Absolute overall potential % assemblage change			**0.0**

METRIC GROUP WEIGHTS

The purpose of this approach is to provide a reasonably objective way to determine the weights of metric groups. An AHP approach is followed where the metric groups are compared pairwise on a 0 – 10 scale with 0.5 intervals.

The objective is to determine the weight of various metric groups as it relates to the natural attributes and requirements of the reference fish assemblage. Introduced species are not a natural attribute or requirement is considered in a different (negative) context.

The basic question is:

Considering

- The natural characteristics of the fish assemblage and its habitat, and
- When comparing a pair of fish metric groups,

which member in the pair would contribute most to a decline or improvement in the fish assemblage integrity if it was to change for whatever reason?

Approach:

The pair with the highest importance in this situation would then receive the highest rating out of 10 with the residue being awarded to the member with the lower contribution. If both members are equally important, both would receive a rating of 5

Considerations:

1. Metric groups: VEL_DEPTH, COVER, FLOW_MOD, PHYSCHEM, the number of species in each metric group, their intolerances as well as habitat characteristics should be taken as the basis of comparison between members of a pair.

2. Metric group: MIGRATION, the number of species with various migration requirements should be considered.

3. Metric group: INTRO, the characteristics and distribution of the introduced species should be considered together with the vulnerability of the indigenous species. This refers only to species that have already been introduced to system and not to species that can po

VELOCITY-DEPTH METRIC GROUP	
VELOCITY-DEPTH	COVER
	10.00
VELOCITY-DEPTH	FLOW MODIFICATION
	10.00
VELOCITY-DEPTH	PHYSICO-CHEMICAL
	10.00
VELOCITY-DEPTH	MIGRATION
	10.00
VELOCITY-DEPTH	IMPACT OF INTRODUCED
	10.00

COVER METRIC GROUP	
COVER	FLOW MODIFICATION
	10.00
COVER	PHYSICO-CHEMICAL
	10.00
COVER	MIGRATION
	10.00
COVER	IMPACT OF INTRODUCED
	10.00

FLOW MODIFICATION METRIC GROUP	
FLOW MODIFICATION	PHYSICO-CHEMICAL
	10.00
FLOW MODIFICATION	MIGRATION
	10.00
FLOW MODIFICATION	IMPACT OF INTRODUCED
	10.00

PHYSICO-CHEMICAL METRIC GROUP	
PHYSICO-CHEMICAL	MIGRATION
	10.00
PHYSICO-CHEMICAL	IMPACT OF INTRODUCED
	10.00

MIGRATION METRIC GROUP	
MIGRATION	IMPACT OF INTRODUCED
	10.00

METRIC GROUP	WEIGHT (%)
VELOCITY-DEPTH	0.00
COVER	20.00
FLOW MODIFICATION	20.00
PHYSICO-CHEMICAL	60.00
MIGRATION	80.00
IMPACT OF INTRODUCED	100.00

EC RESULTS

AUTOMATED	
FRAI (%)	74
EC: FRAI	C
ADJUSTED	
FRAI (%)	74
EC: FRAI	C

D APPENDIX D: VALIDATION OF THE FRAI

D.1 INTRODUCTION AND BACKGROUND

Monitoring data forms the basis of natural resource decisions. There must be confidence in reliability of the data and the interpretations that can be made from it. A fundamental criterion in the selection of numeric values for indicators considers measurability of habitat variables which refers to the ability to achieve desirable levels of accuracy (also expressed as bias) and precision (repeatability). The combination of natural variability and method sample error influences the signal-to-noise ratio while accuracy and precision inherently differ with the monitoring method used (Bauer & Ralph 2001).

An objective of the RHP is the validation of indices used to assess the health and integrity of rivers. This includes the fish response assessment index (FRAI; Kleynhans *et al*. 2005) which is an extension of the fish assemblage integrity index (FAII; Kleynhans 1999). The purpose of the FRAI is to assess present frequency of occurrence of native species in a river reach in comparison to the reference (natural) frequency of occurrence in terms of environmental intolerances and preferences. The FRAI is based on presence-absence of species and is not a fish stock assessment approach. Although abundances are recorded, it is not directly used in the calculation of the FRAI.

Data validation has been defined as a method for ensuring that environmental test results are of known quality. It involves reviewing data against a set of criteria to provide assurance that data is adequate for its intended use.
(http://www.epa.gov/swerffrr/documents/data_quality/dod_oig_2f.htm:
accessed January 2007).

The key issues in terms of validation of the FRAI relates to:

Determination of the similarity between the sampling results of different sampling teams within and between different sites in an ecologically homogenous river reach.

This can be specified in terms of:

- Ho: There are no significant differences in the FRAI results between the sites sampled on the same reach of river.
- Ho: There are no significant differences in the FRAI results between different sampling teams on the same reach of river for any site sampled.

This approach is similar to that followed by Dickens and Graham (2002) in the testing of the SASS (ver.5) index.

D.2 RIVER REACH SELECTED FOR VALIDATION

A reach of the Elands River (tributary of the Crocodile River, Incomati System) between the Elands River waterfall and its confluence with the Ngodwana River was selected for validation (Figure 1). Characteristics of the sites are indicated in Table D.1. Ecoregion and geomorphic zone delineation respectively follows Kleynhans *et al.* (2005) and Rowntree & Wadeson (1999).

Table D.1 Site characteristics.

SITE	DISTANCE BETWEEN SUCCESSIVE SITES (km)	LATITUDE	LONGITUDE	ECOREGION	GEOMORPH ZONE	ALTITUDE
1		-25.644	30.3756	10.02	*D: Lower foothill	1225
2	9.6 km	-25.5960	30.4481	10.03	D: Lower foothill	1105
3	10.3 km	-25.6052	30.5255	10.02	D: Lower foothill	1025
4	3.8 km	-25.5992	30.5525	10.02	D: Lower foothill	1005

*: Valley form:V4,V6; gradient class=0.005-0019;typical channel features= Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plain-bed, pool-riffle or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel or cobble often presents (Rowntree & Wadeson 1999).

The river reach selected is upstream from the influence of a paper mill at the confluence of Elands and Ngodwana Rivers. The river downstream from the mill was subjected to a severe pollution spill in 1989 (Kleynhans et al. 1992).

The Elands River is perennial and 5-15 m wide in the reach investigated. No large flow regulation structures occur in the river. The town of Waterval-Boven is situated approximately 5 km upstream from site 1. Sewage spills from the town are known to have occurred in the past. However, fish kills have not been reported in this section of river.

Land use are mostly devoted to eucalypt and pine plantations, vegetable and fruit farming and some tourist accommodation. Alien riparian vegetation is abundant along some sections.

The instream habitat integrity of this river reach (Kleynhans 1996) was estimated as Class B (largely natural) and for the riparian zone as Class D (largely modified) (Kleynhans 2000).

Overall, impacts on this river reach are generally homogenous and are considered to be minimal to low as far as impacts on the fish assemblages are concerned. This, together with the presence of a fish assemblage and fish habitat features which are similar at all sites, resulted in this reach being selected for FRAI validation.

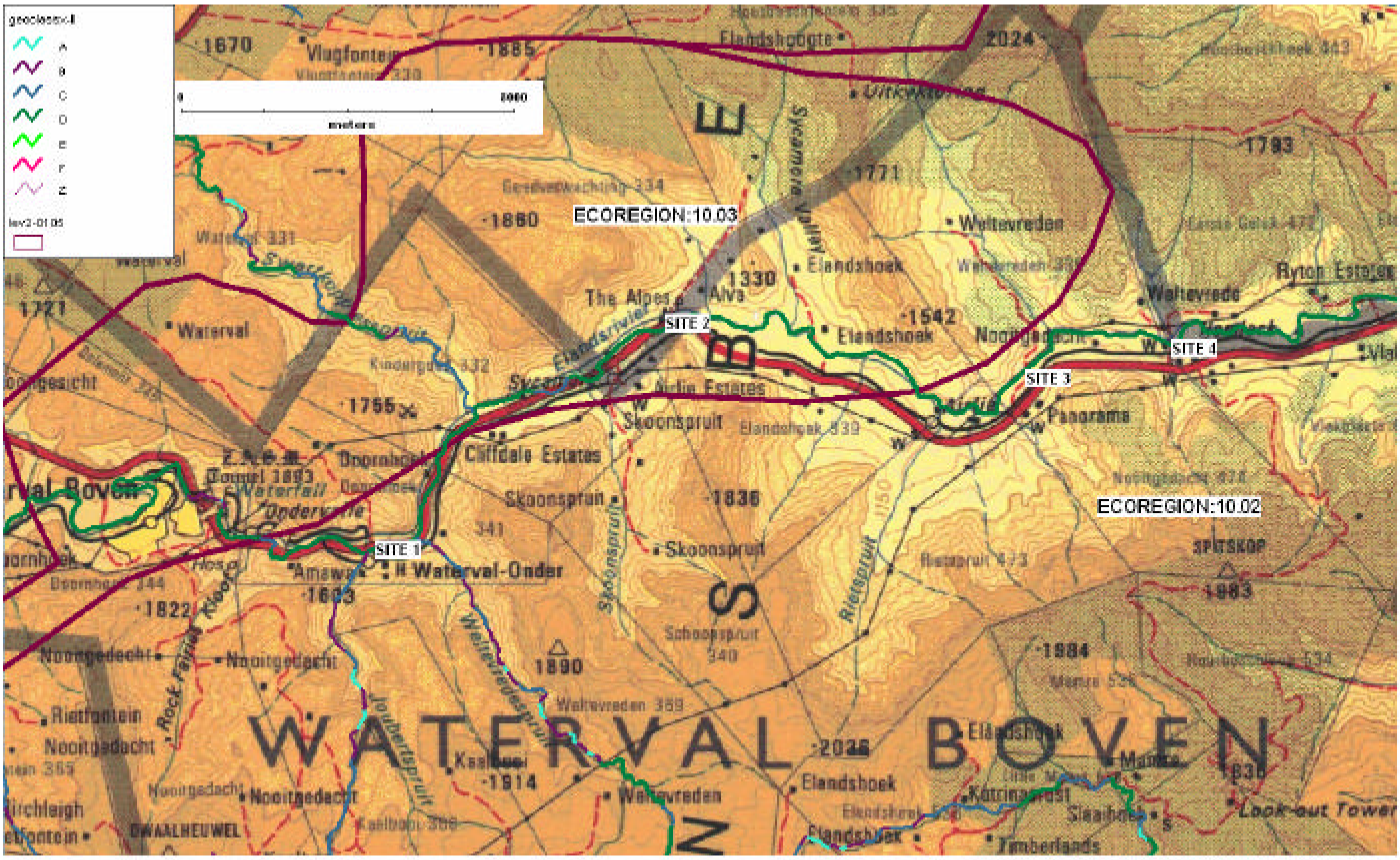

Figure D-1: Sites sampled in the Elands River for FRAI validation.

D.3 METHODS

D.3.1 Fish Sampling

Sampling was done on 11 August 2006 when natural dry season base flow conditions occurred.

Three teams were available to do fish sampling at each site. Only portable AC generators were available for this exercise. The characteristics of the sampling equipment were:

<u>Team 1:</u>

- Electro-shocker: Honda 10I, eu inverter, AC 220v, 50 HZ, rated output=0.900 kva; max output= 1.000 KVA phase1.
- Two circular dipnets:. Diameter = 45 cm; mesh size=1 cm.
- Operators: one handling the electrodes mounted on a fixed A-frame, two handling the dipnets, and situated behind each electrode.

<u>Team 2:</u>

- Electro-shocker: Robin R650; AC 220, 60 HZ, output=0.55 KVA.
- Two circular dipnets:. Diameter = 45 cm; mesh size=1 cm
- Operators: one handling the electrodes mounted on a fixed A-frame, two handling the dipnets, and situated behind each electrode

Team 3:

- Electro-shocker: Honda, AC 220 V, output=5.6 KVA
- Dipnets: one pentagonal, diameter=35 cm, one square, diameter = 40 cm. An additional operator followed these two with a "D" shaped dipnet, dimensions, 60 x 75 cm.
- Operators: Electrodes were separate (not mounted on an A frame) with each operator with a pentagonal net also handling an electrode.

Electro-shocking was done in an upstream direction and following a general zigzag pattern. Fish caught were regularly transferred to buckets.

Effort was recorded as:
The time (to nearest minute) electro-shocking was applied. In this case, Catch per unite effort was expressed as fish caught per minute (Kleynhans 1999; Rogers *et al*. 2005)

River length sampled (m) was recorded by teams 1 & 2. This measure was not used for CPUE calculation. However, the correlation between the time sampled and the river length sampled was calculated.

The majority of fish species in the river have a preference for fast flowing water. In addition these species are also the most intolerant of environmental changes. Consequently, sampling concentrated on fast flowing habitats, e.g. fast-deep (velocity > 0.3 m/s; depth>0.3 m) and fast-shallow (velocity > 0.3 m/s; depth<0.3 m) (Kleynhans 1999). Species with a preference for slow-deep habitat (velocity <0.3 m/s; depth>0.5 m) or slow-shallow habitat (velocity <0.3 m/s; depth<0.5 m) occasionally occurred in the catch.

Only one pass per team per site was done. Sampling was done concurrently by all three teams per site. To prevent the sampling results of the teams from influencing each other, a distance of approximately 50-100 m (at least 1 riffle and pool length) separated teams.

D3.2 Data Analysis

The following approaches were followed:

Within sites

- 1. Determination of the similarity between the sampling results of different teams at each of the sites.

- 2. Analysis of variation of sampling results between teams at each of the sites.
- 3. Calculation of the FRAI per site based on the pooled team data per site. For this the frequency of occurrence of species was based on within site variation (e.g., variation between the results of the 3 teams). This resulted in four FRAI values for the reach (one for each site).
- 4. Calculation of an overall FRAI based on the pooled data per site (cf. point 3). This provided an overall FRAI value for the reach.

Between sites

- 1. Determination of the similarity of the sampling results of each team between the 4 different sites.
- 2. Analysis of variation of sampling results of each team between the 4 different sites.
- 3. Analysis of variation of sampling results between sites when teams' sampling results per site are pooled.
- 4. Calculation of the FRAI based on the pooled sampling results of each team. This resulted in 3 FRAI estimates for the river reach (one for each team).
- 5. Calculation of an overall FRAI based on the pooled results for each team (cf. point 4).

The two "overall" FRAI values indicated above are considered to be the closest approximation of the "real" FRAI.

Similarity analysis of sampling results was based on the presence-absence of both introduced and native fish species. The qualitative version of the Dice-Sorenson index was used (Magurran 1988).

Analysis of CPUE data at all sites indicated that data deviated severely from a normal distribution. Consequently a one-way ANOVA could not be done and the non-parametric Kruskal-Wallis analysis of variance was followed.

PAST software was used for statistical analysis (Hammer et al. 2001).

The FRAI was calculated according to the approach indicated Kleynhans *et al*. (2005). The reference species list and their reference frequency of occurrence for this reach of river used the results of a workshop (Kleynhans *et al*. 2007, in prep.) during which local experts used available data and expert knowledge to determine these (Table 1). The intolerance and preference ratings for these species are the result of a workshop conducted in 2001 (Kleynhans 2003) (Table 2).

Calculation of frequency of occurrence is based on 2 approaches:

- Per site: the number of sampling sections at a site where a species was sampled expressed as a proportion of the total number of sampling sections at a site. In this exercise each site consisted of 3 sampling sections (1 per team).

- Per reach: the number of sites in the reach where a species was sampled expressed as a proportion of the total number of sites in the reach. In this exercise, four sites were sampled.

For the calculation of the FRAI, frequency of occurrence ratings are categorized as indicated in Table D.2.

Table D.2 Reference species list and frequency of occurrence in the Elands River. Based on Kleynhans & Louw (in prep)

SPECIES	ABBREVIATION USED IN TEXT	REFERENCE FROC
Anguilla mossambica	AMOS	4
Amphilius uranoscopus	AURA	5
Barbus anoplus	BANO	5
Barbus argenteus	BARG	5
Labeobarbus polylepis	BPOL	5
Chiloglanis bifurcus	CBIF	4
Chiloglanis pretoriae	CPRE	5
Pseudocrenilabrus philander	PPHI	4
Tilapia sparrmanii	TSPA	3

Table D3 Native fish species recorded in the study reach, and their rated preferences and intolerances

SPECIES	VELOCITY-DEPTH *PREFERENCE				**INTOLERANCE TO NO FLOW				COVER PREFERENCE					**INTOLERANCE: MODIFIED PHYSICO-CHEMICAL CONDITIONS			
	FAST- DEEP	SLOW-SHALLOW	SLOW-DEEP	SLOW-SHALLOW	INTOLERANT: (>4)	MODERATELY INTOLERANT: (>3-4)	MODERATELY TOLERANT: (>2-3)	TOLERANT: (1-2)	OVERHANGING VEGETATION: HIGH->VERY HIGH (>3)	BANK UNDERCUT: HIGH->VERY HIGH (>3)	SUBSTRATE: HIGH->VERY HIGH (>3)	AQUATIC MACROPHYTES: HIGH->VERY HIGH (>3)	WATER COLUMN: HIGH->VERY HIGH (>3)	INTOLERANT: (>4)	MODERATELY INTOLERANT: (>3-4)	MODERATELY TOLERANT (>2-3)	TOLERANT: MODIFIED WQ (1-2)

AMOS	3.4	3.3	3.4				2.8			4.1	4.9					2.5	
AURA	4.6	4.6			4.8						5			4.8			
BANO			4.1	4.3			2.3		4			3.2				2.6	
BARG	3.7	4.3			4.6						5			4.1			
BPOL	3.7	4.3	4.2			3.3					5		3.6			2.9	
CBIF	5	3.3			4.9						5			4.9			
CPRE	4.3	4.9			4.8						4.9			4.5			
PPHI				4.3				1	4.5	3.2							1.4
TSPA				4.3				0.9	4.5			3.6					1.4

*Preference:0=no preference, irrelevant; >0 -1= very low preference - coincidental?;>1-2 = low preference;
>2-3=moderate preference; >3-4=high preference; >4-5=very high preference
**Intolerance: 1-2=tolerant; >2-3=moderately tolerant; >3-4=moderately intolerant; >4-5=intolerant.

Table D.4 FROC ratings used in the calculation of the FRAI

FROC	DESCRIPTION
0	Absent
1	Present at very few sites (<10% of sites)
2	Present at few sites (>10-25%)
3	Present at about >25-50 % of sites
4	Present at most sites (>50- 75%)
5	Present at almost all sites (>75%)

Sampled species data were transformed into frequencies of occurrence on a rating scale of 0-5 by:

FROC = (Nsp/Ns) X 5

Where:
FROC; Frequency of occurrence
Nsp=Number of sites in the reach or sampling points at a site where a species was sampled
Ns=Number of sites sampled in the reach or number of points sampled at a site.
5= Maximum frequency of occurrence of a species.

The following introduced species occur in this reach of the river:

Oncorhynchus mykiss (OMYK) (sporadically in the upper part of the reach)
Micropterus salmoides (MSAL)
Clarias gariepinus (CGAR)
Cyprinus carpio (CCAR)

The potential impact factor for introduced species metrics in the FRAI were fixed at 10% for all sites in the reach. The weights for the FRAI metric groups were set as indicated in Table 4 (cf. Kleynhans *et al.* 2007).

Table D.5 Metric group weights applied to the FRAI for the study reach

METRIC GROUP	WEIGHT (%)
Velocity-depth preferences	95.71
Cover preferences	78.57
Flow modification	87.14
Physico-chemical changes	100.00
Migration	48.57
Impact of introduced species	12.86

Sampling effectiveness:
Species-accumulation curves relate sampling effort (e.g., time electro-fished) to the cumulative number of fish species to evaluate sampling effectiveness. Such a curve was constructed by arranging data according to the time spend sampling by each team and the number of species added during each sampling period. For this purpose the time spend sampling was arranged in ascending order with number of new species added at each time period. This was done for all species (native and introduced) as well as for species with a preference for fast habitat separately. The purpose was to provide an indication of the sampling effort required for the estimation of the FRAI.

D4 RESULTS AND DISCUSSION

D4.1 Catch per unit effort

The species sampled per site by each team is indicated in Table 5. Catch per unit effort is indicated as fish sampled per minute for each species (note that time was not recorded by team 3 at site 2).

Table D.6 Species sampled per min (electro-shocker) at each of the 4 sites

SPECIES	SITE 1				SITE2				SITE3				SITE4				TOTAL FOR ALL SITES
	TEAM 1	TEAM 2	TEAM 3	TOTAL	TEAM 1	TEAM 2	TEAM 3*	TOTAL	TEAM 1	TEAM 2	TEAM 3	TOTAL	TEAM 1	TEAM 2	TEAM 3	TOTAL	
AURA	0.45	0.46	0.22	0.38	0.44	0.71	(30)	0.82	0.38	0.36	1.15	0.57	0.55	0.20	0.75	0.50	**0.58**
AMOS	0.00	0.00	0.00	0.00	0.00	0.00	(0.00)	0.00	0.00	0.07	0.00	0.02	0.05	0.00	0.00	0.02	**0.01**
CPRE	3.02	3.18	1.75	2.67	0.78	1.27	(37)	1.32	1.06	1.67	2.85	1.73	2.05	1.20	2.70	1.98	**1.89**
CBIF	0.00	0.00	0.13	0.04	0.02	0.00	(0.00)	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
CGAR	0.00	0.00	0.00	0.00	0.00	0.00	(0.00)	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	**0.001**
BARG	0.55	0.11	0.28	0.34	1.70	1.88	(33)	2.07	2.73	7.56	4.24	4.78	1.10	2.15	1.15	1.47	**2.42**
BANO	0.05	0.07	0.06	0.06	0.00	0.00	(2.00)	0.02	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.07	**0.03**
BPOL	0.00	0.07	0.13	0.06	0.11	0.04	(19)	0.25	0.04	0.00	0.09	0.04	0.00	0.00	0.05	0.02	**0.10**
MSAL	0.00	0.00	0.00	0.00	0.00	0.00	(0.00)	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.08	**0.01**
TSPA	0.02	0.00	0.03	0.02	0.51	0.00	(11.0)	0.38	0.10	0.64	0.35	0.35	0.95	0.20	0.00	0.38	**0.28**
PHI	0.02	0.07	0.03	0.04	0.05	0.04	(0.00)	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.03	**0.03**
TOTAL	**4.12**	**3.96**	**2.63**	**3.61**	**5.51**	**6.20**	**(202)**	**7.59**	**6.35**	**0.36**	**11.24**	**9.78**	**7.95**	**6.90**	**7.25**	**7.37**	**5.37**
TIME (min)	**42.00**	**28.00**	**32.00**	**102**	**63.00**	**51.00**	**-**	**114**	**52.00**	**45.00**	**34.00**	**131**	**20.00**	**20.00**	**20.00**	**60.00**	**406.00**
LENGTH (m)	**50**	**42**	**-**	**92**	**57**	**64**	**-**	**121**	**53**	**61**	**-**	**114**	**40**	**39**	**-**	**79**	**(407.00)**
NATIVE SPP	**6**	**6**	**8**	**8**	**7**	**5**	**6**	**8**	**5**	**5**	**5**	**6**	**5**	**5**	**5**	**8**	**9**
TOT NO SPP**	**6**	**6**	**8**	**8**	**7**	**5**	**6**	**8**	**6**	**5**	**5**	**7**	**6**	**5**	**5**	**9**	**11**

***Only Numbers Caught**
**** Indigenous and Introduced**

Analysis of CPUE data at all sites indicated that data deviated severely from a normal distribution. Consequently a one-way ANOVA could not be done and the non-parametric Kruskal-Wallis analysis of variance was followed. In addition, the FRAI is based on frequency of occurrence in combination with intolerance and preferences and not on abundances as such. It follows that statistical analyses based on ranking and presence-absence would be appropriate.

The correlation between the time and the distance (river length; only for teams 1 and 2) was calculated as r = 0.8560.

D4.2 Analysis of Variance

Table 6 indicates the level of statistical significance for the Kruskal-Wallis for all 4 sites (team data pooled for each site) as well as for all sites pooled. The following is evident:

Within site variance:

- All species considered: A significant difference between teams at sites 1 and 2 when all species (native and introduced, and regardless of velocity depth preference) are considered.
- Only native species with preference for fast habitat (Table 2): No significant differences between teams at any of the sites.

Between site variance (all sites and team data pooled):

- No significant difference between sites.

Table D.7 Kruskal-Wallis analysis of variance of sampling results at the four sites and all 4 sites combined

SITE	ALL SPECIES		ONLY INDIGENOUS SPP WITH PREFERENCE FOR FAST FLOWING HABITAT (AMOS, AURA, BARG, BPOL, CPRE, CBIF)	
	KRUSKAL-WALLIS p-LEVELS	KRUSKAL-WALLIS SIGNIFICANCE	KRUSKAL-WALLIS p-LEVELS	KRUSKAL-WALLIS SIGNIFICANCE
1	0.25	S	0.09	NS
2	0.42	S	0.0	NS
3	0.003	NS	0.14	NS
4	0.09	NS	0.06	NS
All sites combined	0.08	NS	0.01	NS

D4.3 Similarity Indices

Tables 7 & 8 respectively indicate the Sorenson-Dice similarity coefficients between teams at the sites and between sites (all team data pooled per site) for all species and native species with a fast flow preference. Especially where only native species with a preference for fast flows were considered, similarity coefficients were very high.

Table D.8 Sorenson-Dice similarity coefficients for all four sites and teams: All species and only native species with a fast flow preference included.

SITE	TEAM	ALL SPECIES			ONLY NATIVE SPP WITH PREFERENCE FOR FAST FLOWING HABITAT (AMOS, AURA, BARG, BPOL, CPRE, CBIF)		
		1	2	3	1	2	3
1	1	-			-		
	2	0.83	-		0.89	-	
	3	0.73	0.73	-	1	0.89	-

2	1	-			-		
	2	0.73	-		0.89	-	
	3	0.73	1.00	-	0.89	1	-
3	1	-			-		
	2	0.89	-		0.86	-	
	3	0.80	0.89	-	0.75	0.86	-
4	1	-			-		
	2	0.86	-		0.86	-	
	3	0.86	0.75	-	1	0.86	-

Table D.9 Sorenson-Dice similarity coefficients between sites: all species and only native species with a fast flow preference included.

SITE	**ALL SPECIES**				**ONLY NATIVE SPECIES WITH FAST FLOW PREFERENCE**			
	SITE				**SITE**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	-				-			
2	0.93	-			1	-		
3	0.71	0.77	-		0.80	0.8	-	
4	0.77	0.67	0.73	-	0.89	0.89	0.89	-

D4.4 Sampling effectiveness:

The maximum number species known from this reach of river is 11. The species accumulation curve in Figure 2 indicates an asymptote at about 8-9 species and an accumulative sampling effort of 60-80 minutes. At this sampling effort, more than 80% of all species are sampled. At this stage, 80% of all species is assumed to provide enough information to calculate a representative FRAI. However, this needs to be confirmed for a river with higher species richness.

The maximum number of native species with a preference for fast flowing water is 6. The species accumulation curve in Figure D.2 indicates an asymptote at 5 species with an accumulative sampling effort of 60- 80 minutes.

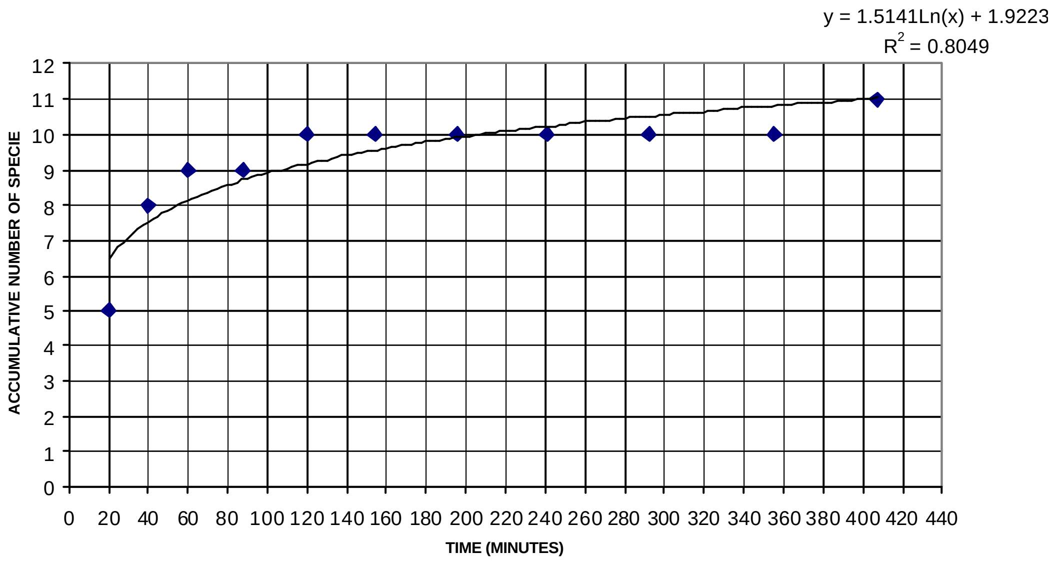

Figure D.2 Number of species (introduced and native) caught per accumulative effort

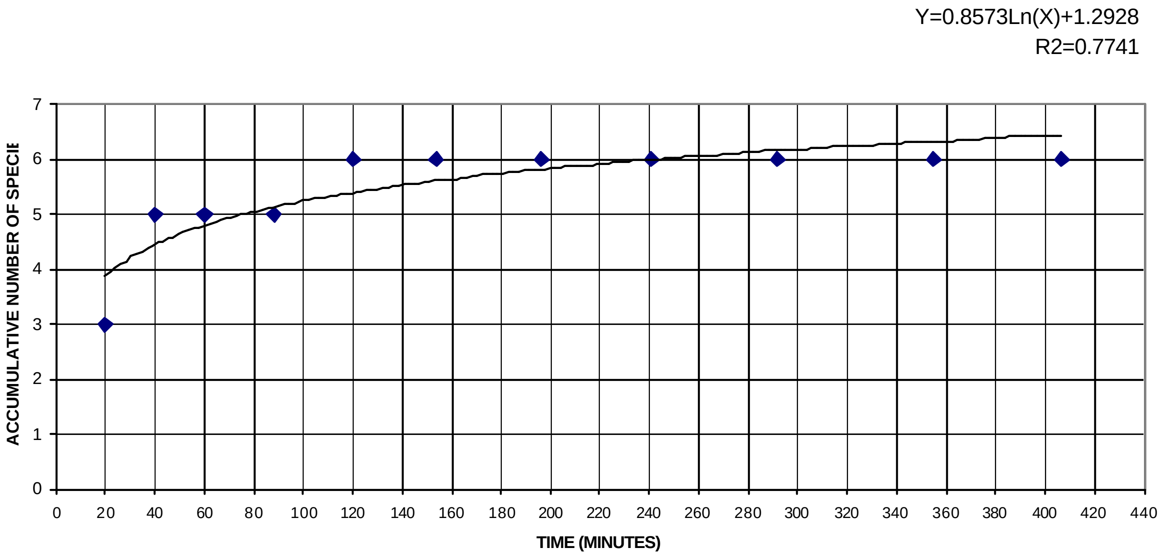

Figure D.3 Number of native species with a preference for fast flowing water caught per accumulatie effort

D4.5 FRAI assessments

From Tables 9 & 10 it is evident that data pooled for all sites or for teams, indicate a FRAI category of B/C when only native species with a high preference for fast flows are considered. This is considered to be a better indication of the FRAI category than a scenario including all native species. Species with a preference for slower flowing habitats were mainly caught at quiet spots in fast flowing sections. Due to time limitation, slow flowing habitats were not specifically targeted for sampling. However, intolerant species and species with particular habitat preferences were predominantly present in fast flowing habitats (Table D.2).

When data from all sites are pooled or the data from all teams were pooled, a FRAI category of "A" is arrived at. This is judged to be a high confidence indication of the "real" FRAI value and category for this reach of the river. The implication of this is that the FRAI value based on either pooled data per site or individual team data pooled is an underestimation of the real FRAI. This underestimation can be "adjusted" for by also considering the habitat integrity of the river reach as is discussed in Kleynhans, *et al.* (2007). Expert knowledge is used to consider the likely presence of low abundance species (e.g. *Chiloglanis bifurcus*) or species that are difficult to sample (e.g. *Anguilla mossambica*). This judgment is based on assessment of present habitat conditions and interpretation of its suitability for species when considering their intolerances and preferences. The assessment of available habitat conditions limits the amount of time and sampling effort required to provide a high confidence estimation of the FRAI.

Two approaches can be followed to adjust the FRAI calculated by the model:

- 1. The habitat integrity is considered and the ratings for each of the appropriate metric groups (velocity-depth, cover, flow modification and physico-chemical) are changed where judged necessary.
- 2. The habitat integrity is considered and the observed frequency of occurrence ratings for each species is adjusted accordingly.

The habitat adjusted FRAI based on approach (1) above, increases the site-pooled and team-pooled FRAI values to 91.8% (category A/B) (Tables D.10 & D.11) which is comparable with the 94.4% which is considered the "correct" FRAI value.

Assessment of the macro-invertebrate integrity based on SASS5 indicates a category of A/B to A for this river reach (Thirion pers. comm. 2007).

Table D.10 FRAI values based on team data pooled per site and all sites pooled

	SITE 1 POOLED	SITE 2 POOLED	SITE 3 POOLED	SITE 4 POOLED	ALL SITES POOLED
ALL SPECIES	82.7	82.7	59.3	63	90.4
FAST FLOW SPECIES	81.2	81.2	80.5	80.5	94.4
FRAI CATEGORY: FAST FLOW SPECIES	B/C	B/C	B/C	B/C	A
TIME SAMPLED (min)	**102**	**114**	**131**	**60**	**407**

Table D.11 FRAI values for team data pooled for all sites and all team data pooled.

	TEAM 1	TEAM 2	TEAM 3	TEAMS

	POOLED	POOLED	POOLED	POOLED
ALL SPECIES	71.2	65.1	76.2	91.3
FAST FLOW SPECIES	81.4	78.2	78.8	94.4
FRAI CATEGORY: FAST FLOW SPECIES	B/C	B/C	B/C	A
TIME SAMPLED	147	144	116	407

D.5 CONCLUSIONS

- 1. Although mainly fast flowing habitats were sampled, the same principles would apply if slow flowing habitats were sampled. This means that the reference frequency of occurrence for species in slow flowing habitats would be compiled against the observed and derived present frequency of occurrence.
- 2. Considering native species only, within site and between site variance is not statistically significant. This means that despite the differences in sampling apparatus, the data of teams at different sites and from different teams are comparable and largely similar. This applies to the presence of native species with a preference for fast flow in particular.
- 3. The calculation of the FRAI based on species with a preference for fast flow and using different combinations of pooled data (Tables 9 & 10), indicates that the FRAI calculated per site and per team is in a “B/C” category. However, when all data is pooled the FRAI category increases to “A” which is considered to be the “actual” FRAI category for the reach. This indicates that sampling on which the pooled data (per site and per team) was not sufficient to provide the “actual” FRAI value and category.
- 4. When taking habitat integrity in this reach into account, the FRAI category for the pooled site and team data increases to “A/B”.

D.6 GUIDELINES AND RECOMMENDATIONS FOR APPLICATION AND INTERPRETATION OF THE FRAI

Based on the investigation on this particular river, it is recommended that the following be followed for determining the FRAI in rivers in general and the RHP in particular:

- 1. The river reach assessed (resource unit or assessment unit), should be relatively homogenous in terms of its natural features. If necessary, the assessment unit should be subdivided into sections of homogenous impact. The approach followed for this purpose is described in the VEGRAI module of the EcoStatus manual (Kleynhans et al., 2007.). The objective is that the site selected for FRAI assessment should be as representative of the river reach or sub section as possible.
- 2. In practice it is usually not possible to select more than one site per assessment unit for River Health Programme purposes. As this investigation

indicated, this is likely to provide an underestimation of the FRAI. This underestimation can be reduced by sampling different separate section of river length at each site. At least three such sections should be sampled and results recorded separately. This will provide data that can be used to calculate the frequency of occurrence of species at the site (which is assumed to be representative of the reach).

- 3. The sampling effort per site should be at least 60-90 minutes (e.g. 3 sections each sampled for 20-30 minutes). However, it is recommended that the distance sampled should also be recorded. In terms of distance, the time shocked will relate to a total distance of approximately 60 m to 75 m.
- 4. Where only one site per assessment unit can be surveyed (as indicated above), it is essential that the habitat integrity of the unit be assessed at as many points as possible to get a representative picture of fish habitat condition. This information should be used to assess whether any of the frequency of occurrence of species should be adjusted, or whether the metrics within certain metric groups (velocity-depth, cover, flow modification and physico-chemical), should be changed from the model results. The decision to adjust the FRAI ratings should consider whether the site is sufficiently representative of the whole assessment unit. If this is not the case, it may be necessary to subdivide the assessment unit into appropriate units to ensure that representativeness (cf. point 1).
- 5. It is essential that the fish sampling data that is used in the FRAI be interpreted in terms of the velocity-depth classes that were sampled. In this investigation, fast flowing habitats were sampled, but species with a preference for slow flows can be present at 'slow' spots in fast flowing sections. The presence of such species should be recorded but not taken into account in the calculation of the FRAI that will in this case be based on species with a preference for fast habitat. In cases where the fish assemblage is constituted mainly from species with a preference for slow flow, these velocity-depth classes should be concentrated on when sampling. Usually, species with a preference for fast flow are also those most intolerant and indicative of environmental changes. This consideration is taken account of in the EcoStatus models.
- 6. From point 5 it follows that a representative survey of fish at a site should ideally sample all habitats (e.g., fast and slow) and this data should be included in the overall assessment of the FRAI.
- 7. Electro-shocking is considered to be the most practical way for sampling fish in wade-able streams (<0.7 m deep). This includes both fast and slow flowing habitats. . It is suggested that where-ever possible, sampling be conducted by electro-shocking in both fast and slow flowing habitat. In slow flowing habitat, information can be augmented by using small seine nets.
- 8. Larger non wade-able rivers or sections of rivers can also be sampled by electro-shocking from a boat (usually concentrating on the river margins) (Pont *et al.* 2006) but guidelines for the application of this sampling approach should be developed and assessed separately.
- 9. From this investigation it appears that the type of electro-shocking apparatus did not have a major influence on the sampling results as far as requirements for

FRAI calculation was concerned. Only AC electro-shockers were used and this necessitated a team of at least three people. It is necessary that other electro-shockers, such as small, back pack, battery powered apparatus be evaluated for use in FRAI determination. Such equipment is often used where there is a labour limitation. The FRAI is based on presence-absence and frequency of occurrence and the type of shocker is not expected to have a large influence on the sampling results. However, single operator back-pack shockers will have to be tested and compared with AC shockers as used during the current validation.

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