BIOLOGICAL CONDITION GRADIENT (BCG) FOR THE UPPER TANA, KENYA

Macroinveterbrates, Birds, Fish, Amphibians & Vegetation

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EXECUTIVE SUMMARY

Introduction

The need to manage waters resources in Kenya is well captured in the Water Act 2002, which established the Water Resources and Management Authority (WRMA) that has given the authority the national mandate to regulate and manage water resources. Key to management of water resources is establishment of monitoring and management initiatives, with each of the six major catchment areas developing a Catchment Management Strategy (CMS). The CMS borrows heavily from National Water Master Plan 2030 and its main objective is to support the management of the water resources environment and human behaviour in ways that achieve equitable, efficient and sustainable use of water for the benefit of all users (WRMA website, http://www.wrma.or.ke). The Tana Catchment Area (TCA) is one of the six catchment areas, with the other five being Lake Victoria North Catchment Area, Lake Victoria South Catchment Area, Rift Valley Catchment Area, Athi Catchment Area and Ewaso-Ngiro North Catchment Area.

The Tana Catchment Area (TCA)'s CMS observes that there are several challenges undermining sustainable management of waters resources and attributed them to inadequate data on the ecological status, specifically on: (i) biological quality elements, (ii) chemical and physicochemical quality elements, including pollutants being discharged in significant quantities, and (iii) hydromorphological quality elements (WRMA 2014). In addition, the TCA's CMS has experienced difficulties in interpreting the data when attempting to determine to which extent an ecosystem has changed, for instance from the hypothesized natural state or reference point and with most managers opting to rely on expert judgment to determine ecological status based on presence of biological species rather than on water quality measurements. As result, TCA has classified surface water status into three crude classes of satisfactory, alert and alarm; which have very minimal utility in identifying stressors hence inappropriate for formulating appropriate management options (WRMA 2014).

It is widely recognized that wetlands[1] are the sources of water and most studies on wetland ecosystems also include water quality (Crafter et al. 1992, MENR 2012). The need to halt wetlands loss and degradations has witnessed initiation of several small to large scale studies with an aim to gather information to support sustainable management of wetlands in the country. These studies are either based at local, counties, regional and national levels, with most of the studies carried to determine ecological health of wetlands using various parameters, including water quality, biodiversity and socioeconomic parameters. Unfortunately only a small percentage of these data are published with most of the information obtained scattered in unpublished sources that if compiled and analyzed can be very beneficial in supporting conservation and restoration of wetland ecosystems in the country. Even the little published have challenges of not

1 *In this report wetlands are described according to RAMSAR 2011 as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres."*

being in form that is easily understood by those entrusted with management of the environment (MENR 2012).

The need for environmental condition monitoring tool

One framework that environmental managers require is a tool to inform them on the conditions of habitats under their management. The tool should be able to capture and describe the ecological conditions of aquatic ecosystems as well as that of their watersheds. For over a century, water assessment and monitoring have been conducted using biological indicators. It started with the Saprobien System concept in early 1900 (Davis 1995) that used benthic macroinvertebrates and planktonic plants and animals as indicators of organic loading and low dissolved oxygen (DO). It has been updated since its initial development and is currently used in several European countries, where the Saprobien System and lake trophic state classifications describe a response gradient (or response classes for lakes) to pollution from human and natural influences (e.g. Vollenweider 1968, Beck 1954; Pantle & Buck 1955). In summary, these developments have led to today's integrity biotic indices, IBIs (Davis 1995). Some of the biotic indices use diversity indices based on information theory to describe changes in community structure, richness and dominance (evenness) as a measure of pollution effects (e.g. Wilhm and Dorris 1966). The IBI integrates the concept of anchoring the measurement system in undisturbed reference conditions with the measurement of several indicators intended to reflect ecological components of composition, diversity and ecosystem processes. It thus combines a conceptual model of ecosystem change in response to increasing levels of stressors with a practical measurement system.

The strong links that exist between watersheds and water quality in wetlands (Masese et al. 2012, Minaya et al. 2013) show terrestrial biological indicators are also important components of wetland assessment and monitoring programs because they have a utility to identify threats and causes of environmental degradation in watershed as well as in wetlands. Just like in wetlands, changes in terrestrial ecological components of species composition, diversity and ecosystems can be used to model ecosystem change due to increasing levels of stressors. In conclusion, biological indices that are relevant to sustainable management of wetlands and associated watersheds should incorporate both wetlands and terrestrial biological indicators. The United State Environmental Protection Agency's Biological Condition Gradient (US EPA BCG) that is grounded in the concepts of stress ecology articulated by Odum et al. (1979), Odum (1985), Rapport et al. (1985) and Cairns et al. (1993), start by describing "natural" conditions and then determine change in biological condition caused by stressors is a robust and appropriate index that can be designed to describe environmental conditions in both wetlands and watersheds.

Initially, the BCG was developed based on USA state biologists' experiences with water quality management (Courtemanch et al. 1989, Yoder and Rankin 1995a, Davies et al. 2016), as well as the practical experience of a diverse group of aquatic scientists from different bio-geographic areas (Davies & Jackson 2006). Meanwhile the BCG has utilities that can be used to describe ecological conditions in UT and the entire TCA, and in doing so can assist to overcome challenges of obtaining and interpreting complex scientific data for sustainable management of waters resources in TCA. A keen examination of the BCG shows that it can be simplified and adapted to fit a number of situations. Unlike other IBIs, BCG can be easily used by non-experts who are often key stakeholders in conservation. Indeed a pilot study to develop and use the USEPA's BCG in the Upper Tana River (UT) watershed showed that the BCG has built-in utilities including simplicity, versatility and its robust nature, which can be applied to monitor, assess and communicate habitat condition. Herein, BCG models are described for both aquatic and terrestrial taxonomic groups of macroinvertebrates, fish, amphibians, birds and plants by using relevant attributes from the original BCG. Further incorporation of real data of macroinvetebrates and birds into BCGs models showed each taxonomic group complemented each other and reliably assessed habitat conditions in UT. Future studies in the UT watershed recommend the use of all taxonomic BCGs models to assess water and landscape condition.

Description of Biological Gradient Condition

The BCG is a conceptual, scientific framework for interpreting biological response to increasing effects of stressors on aquatic ecosystems (USEPA, 2016). The framework was developed based on common patterns of biological response to stressors observed empirically by aquatic biologists and ecologists from different geographic areas of the United States. The framework describes how nine characteristics (attributes) of aquatic ecosystems change in response to the increasing levels of stressors, from an "as naturally occurs" condition (e.g., undisturbed/minimally disturbed condition) to severely altered conditions (see Table 1). The BCG describes characteristics of aquatic ecosystems that are typically measured by USA's state water quality management programs that change in response to increasing levels of stress (Figure 1). The characteristics are defined as "attributes," and include aspects of community structure, organism condition, ecosystem function, and ecosystem connectivity.

The BCG framework can be considered analogous to a field-based dose-response curve where the dose (x-axis) represents increasing level of natural and anthropogenic stress, and the response (y-axis) represents biological condition. For example, high concentrations of certain metals, nutrients, or sediment can adversely impact or stress aquatic biota. Loss of suitable aquatic habitat or presence of aquatic invasive species can also adversely impact the aquatic biota expected for a specific water body. These stressors can cause aquatic ecosystems to change from natural conditions, including naturally occurring stress, and exhibit altered compositional, structural, and functional characteristics. The degree to which stressors affect the biota depends on the magnitude, frequency, and duration of the exposure of the biota to the stressors. Developing a BCG for a given system characterizes the general relationship between its stressors in total and a water body's overall biological condition. Stressors can include a wide range of independent or co-dependent causes such as water pollution, temperature, changes in water volume or flow, habitat alterations and modifications including wetland and terrestrial, exotic species introductions, or resource exploitation (e.g. overfishing). Multiple stressors are usually present, and thus, the stress x-axis of the BCG seeks to represent their cumulative influence as a Generalized Stress Axis (GSA), much as the y-axis generalizes biological condition. The x and y axes of the BCG serve as a framework to organize, relate, and help reconcile the mosaic of factors and interactions that exist, parts of which will be characterized and measured using biological, chemical, physical, and/or land use/land cover indicators.

The BCG seeks to explain how biological entities respond to cumulative effects of stressors in an ecosystem, which are described as Generalized Stress Axis, GSA (Figure 2). As a theoretical construct, the GSA seeks to represent the cumulative stress that may influence biological condition. The conceptual GSA provides a framework to assist in development of as comprehensive and robust a quantitative stress gradient as possible to support BCG development. A well-defined, quantitative GSA, and the underlying data used to develop it, may serve as a nexus between biological and causal assessments, thereby linking management goals and selection of management actions for protection or restoration of ecosystems. It is promising that systematic testing of technical approaches to define and apply a GSA to BCG development has seen several studies conducted in pilot levels in USA (USEPA 2016). Opportunities in the future may include quantify a GSA for a specific geographic region and water body type throughout the world.

The utility and application of BCG

The BCG was conceived to help to make sense of the biological complexity encountered when one looks at the living characteristics of our waters (Davies and Jackson 2006; Figure1). Consistent differences in community structure and function are known to occur in aquatic assemblages as they are subjected to increasing levels of human presence and disturbance. The BCG provides an ecologically detailed description of commonly observed stages of change across six steps or tiers. Six tiers have been found to show sufficient differences to inform management decisions without becoming too complicated. Tier I describes the expected biological characteristics of naturally occurring aquatic assemblages where the human presence is small and relatively inconsequential, and provides the base condition from which the gradient is built. At the other end of the gradient, Tier VI describes the alteration of the aquatic assemblage for severely stressed and degraded waters. The BCG is built upon the observations, measurements, and experience of research scientists and water quality specialists across this gradient of natural to severe stress (Figure 2). The model distills this information into an easily understood and readily communicated progression of altered biological condition in response to human disturbance. One does not have to fully understand all that the BCG describes about stress-induced changes among the ecological attributes on which it is built. In its simplest form, the BCG provides a readily accessible, six-part measuring stick to facilitate conversations about environmental values. It condenses the complexities of “data” by creating a bridge between scientific observations and their meaning. It helps even the untrained to interpret the implications of complex ecological data in relation to their own environmental values. To enter the conversation, it is enough to simply know in what BCG Tier a waterbody falls, and then to consider that condition in relation to one's hoped-for condition for that water. This information can be looked at in the context of a specific water body or at larger scales to look at the extent and distribution of conditions across a watershed. In summary, well-designed biological assessment organizes and assembles scientific evidence about ecosystem condition and the BCG provides a common translation tool that empowers anyone to participate in a conversation about what it means, what is of value, and if something needs to be done. Biological assessment is an indispensable tool if we hope to arrive at a full understanding of the value of our waters and ecosystem services they provide. While the BCG does not directly evaluate human benefits, the higher quality tiers generally represent waters that provide a full suite of ecosystem services including higher quantity and quality potable and domestic supply, higher value fishery resources, and quality more beneficial for agricultural and commercial uses.

From a management perspective, the tiers can provide helpful guidance. At this time and across many parts of the world, **Tier I** waters may be rare and, when found, certainly deserve a high level of protection. **Tier II** waters, while clearly affected by human presence, are similarly high quality but represent a condition where human use, land practices, and other effects are mitigated through good stewardship. **Tier III** waters are good quality and support many of the organisms and functional qualities of Tier I or II. **Tier IV** indicates a condition where there has been substantial disturbance and alteration in the ecosystem but where ecosystem functions are at least marginally maintained. Tier IV is often considered to be the minimally acceptable condition. **Tier V** is a condition where structure and function are deficient but where management actions can be expected to improve the ecological condition. **Tier VI** is severely altered and depending on the source and magnitude of disturbance may be a lower priority for recovery, may require significant resources for recovery, or may be determined unrecoverable. The management objective should not be to bring all waters to a Tier I or II condition or to manage waters upward or downward to only a minimally accepted condition (Tier IV). Rather, waters should be managed to optimize their ecological values relative to their landscape context, deployment of best management practices and sustainable use practices. Such a management approach should lead to general improvement along the gradient.

Development of BCGs for the Upper Tana

The development of BCGs for the UT commenced with compilation and analysis of biological data of the five taxonomic groups, including macroinvertebrates, birds, vegetation, fishes and amphibians. Experts' workshop was held during which experts familiar each of the five taxonomic groups were tasked to assess and define each of the species preferred ecological conditions. The final phase comprised experts assigning and placing various sites to BCG Tiers using species assemblages. The suitability of each taxonomic groups and BCG models developed are summarized below.

Macroinvertebrates: It was evident from literature review that considerable information exists on macroinvertebrate assemblages and their associated ecological conditions. Pristine rivers and streams had a variety of species that were characteristic of their less disturbed habitats such as high diversity and relative abundance of insects in the taxonomic orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) otherwise commonly referred to as EPT taxa. Pollution tends to eliminate sensitive taxa such as EPT. On the other hand, degraded habitats were dominated by certain taxa representing pollution-tolerant organisms such as earthworms (Tubificidae), midge fly larvae (Chironomidae), crane fly larvae (Tipulidae) and non-bottom dwellers such as diving beetles (Dytiscidae) and water boatmen (Corixidae). Pollution and disturbance affected the physical, chemical, and biological conditions of habitats that caused a reduction in the diversity and abundance of sensitive taxa. They may also lead to changes in community structures such as a lower percentage of EPT taxa and a higher percentage of pollution tolerant species. Macroinvertebrates indicate habitat impacts even those not detectable by traditional water quality assessments. Using information compiled, a provisional macroinvertebrates BCG was developed for the UT (Table 3). In addition a list of macroinvertebrates found in UT and their expected population responses to increasing stress levels is given as Appendix 1.

Birds: Birds are often considered as a useful indicator group, either for monitoring environment change (Furness & Greenwood 1993, Bryce et al 2002) or for assessing biodiversity importance (e.g. Stattersfield 1998). Their usefulness is derived from their relative ease to observe, count and identify (Pomeroy 1992). Many bird species respond strongly to structural characteristics of the habitats they live in, e.g. the extent of forest degradation will have a corresponding impact on the species diversity and abundance. Though these impacts may be detected by simple lists, densities give a deeper insight of the ecological interactions at individual or community scale (Opdam & Wiens 2002). Bennun et al (1996) developed a simple classification system for East African Forest birds that goes further than species list and detects subtle differences between forest avifaunas in both space and time. The classification system has three categories:

i. Forest specialists- which are the ‘true’ forest birds characteristic of undisturbed forest,

ii. Forest generalists- which may occur in undisturbed forest but are also regularly found in forest strips, edges and gaps. They are likely to be commoner there and in secondary forest than in the interior of intact forest,

iii. Forest visitors-which are often recorded in forest, but are not dependent upon it. They are almost always more common in non-forest habitats, where they are most likely to breed.

Using proportions of birds in each category in the classification system can be usefully applied to develop indices that indicate various forest conditions (Furness & Greenwood 1993, Bryce et al 2002, Bennun et al 1996). This was used in an attempt to build a BCG for birds in the UT, putting into context birds are sensitive to vegetation or habitat quality. Based on the outcome of a preliminary survey of birds in the Upper Tana and the experts knowledge a probable ecological attribute versus condition tier matrix for the UT was develop (Table 4), with expected response of some birds to environmental stress provided in Appendix 2.

Vegetation: The vegetation in the UT watershed play an important role in maintaining water quality and quantity, providing areas where runoff water and sediment are stored and naturally filtered. However, since the 1970s, the unprotected forests and woodlands including those in steep hillsides, rivers and areas of wetlands have been converted to agriculture. Majority of the forests area from lower edges in woodlands and up to the afromontane zones have been converted to farmlands growing tea, coffee and food crops, safe for the protected national parks and forests.

Evidently the ecological conditions of watersheds are directly linked with water quality in wetlands as such any serious conservation and interventions activities must also consider the restoration of watersheds. A quick assessment of vegetation communities in the catchment is enough to inform the environmental conditions of the watershed. Meanwhile riparian habitats are botanical hotspots, due habitat heterogeneity provided by unique characteristics along streams, river banks, floodplains and associated wetlands (Ledec 1987, Maingi & Marsh 2006), that underpins their importance in supporting and maintaining ecological processes and functions in landscapes (Hitoshi & Toshikazu 2008). For instance forests are key sources of food, cover, and water, and serve as migration routes and habitat connectors for a variety of wildlife. They also help control water pollution, reduce erosion, mitigate floods and increase groundwater recharge.

Some group of plants species especially bryophytes, lichens and ferns react differently to change in environmental conditions and therefore are a good for monitoring forest quality and level of disturbance. Other species in these specialists group show narrow range of habitat requirements and as such are highly affected by slight alteration of their preferred local habitats. Species patterns in different localities are a good indicator of how species respond to different conditions/stress occasioned by human or natural disturbances as well as natural influences. Such species will be used as indicators of magnitude of disturbance in different wetlands and terrestrial study sites. Some specific plant species especially herbaceous layer show a clear habitat differentiation in relation to light intensity/conditions, moisture availability and disturbance levels, therefore making them suitable indicators of anthropogenic disturbance. The presence of invasive/weed species is also good indicator of disturbances levels.

Based on experts' knowledge and experience on vegetation, it was possible propose a hypothetical BCG on vegetation for the UT (Table 5). Weedy and invasive species are known to prefer open and degraded areas while intact and pristine habitats tend to support secondary to primarily vegetation cover. Meanwhile areas under transition are likely to support mixture of vegetation species. Overall, the expected responses for a number of vegetation species to environmental stresses are provided in Appendix 3.

Fishes: Fish are very good indicators of change because their mobility and sensory perception which enable them to avoid environmental perturbations. The presence, absence and proportionate abundance of fish can be used to indicate the quality of physical, chemical and biological conditions of aquatic environments in which they live (Karr et al. 1986).

One of the tools used for monitoring change using fish has been the use of Index of Biotic Integrity (IBI), which was originally developed for fish assemblages in small streams in Midwestern United States of America (Karr et al. 1986). The IBI uses attributes of the fish assemblage in a stream reach to assess the condition of a stream and its catchment, relative to eco-regional standards. The IBI integrates land-water linkages, physical habitat quality, hydrological regime, energy inputs, biological interactions and water quality (Karr et al. 1986, Steedman 1988). Using a similar approach in Kenya, Raburu & Masese (2010) developed a Fish Based Index of Biotic Integrity (FIBI) for monitoring riverine ecosystems in the Lake Victoria drainage basin.

Based on these studies, the following can be concluded on the response of fishes to environmental stress. Fish species considered to be intolerant to pollution include *Mormyrus kannume, Gnathonemus longibarbis, Enteromius neumayeri, Labeobarbus altianalis, Oreochromis variabilis*, *Schilbe mystus* and *Bagrus docmak* (Raburu & Masese 2010). Mormyrids are known to be sensitive to degradation, especially sedimentation, because it affects their stream bed habitat (Hugueny et al. 1996, Toham & Teugels 1998). The Genus *Oreochromis* is generally considered to be tolerant to physico-chemical changes (Raburu & Masese 2010). A descriptive BCG model on fish for the UT region and each fish response to f environment stress are provided as Table 6 and Appendix 4, respectively.

Amphibians: Amphibians are one of the animal groups that play an important role in the food webs of most biological communities (Scott & Seigel 1992). Naturally amphibians are very sensitive to environmental change due to their permeable thin skin that makes them vulnerable to chemical and physical changes in both terrestrial and aquatic habitats (Bell & Donnelly 2006). The survival of the amphibian fauna all over the world is under threat as a result of a variety of causes, apparently related to global climate change, which is attributed to habitat alteration through habitat loss, degradation, modification and disturbance. Other threats to amphibians are pollution and diseases such as fungal infection.

Use of amphibians to monitor environmental conditions in the UT Watershed is justified by the fact that 54 amphibian species are known to occur in central and western highlands of Kenya (Lötters et al. 2006). This is a significant number of anurans particularly when considered that there are approximately 100 Amphibian species known from Kenya (Channing & Howell 2006, NMK Herpetology collection). There are about 21 species of frogs found in the UT watershed, of which 13 species are widespread while the rest are more Kenyan highlands endemic (Appendix 5). Specific information used to describe amphibians' BCG for the UT were species presence/absence, population sizes, body size, age structure, fecundity and health status (Table 7).

Conclusions and recommendations

Conclusions

1. Biological Condition Gradient (BCG) metrics are simple and robust methods of assessing and monitoring ecological conditions.
2. Present BCG metrics in use in USA are based on aquatic taxonomic groups of fish, macroinvertebrates, macrophytes and diatoms. During this exercise there was evidence BCG metric can also be developed for both aquatic and terrestrial ecosystems using fish, macroinvertebrates, birds, amphibians and vegetation.
3. It was noted that a strong link exists between terrestrial and wetlands, hence monitoring of wetlands conditions should be linked and extended to terrestrial landscapes.
4. Just like in USA, macroinvertebrates were found to be suitable for monitoring streams and river in the UT.
5. Assessment of bird fauna in the same areas where macroinvertebrates were being assessed found that the birds provided complementary information about habitat condition.
6. For some taxonomic groups considered, data on species occurrences, distribution and abundances were found to be insufficient.

Recommendations

1. There is need to conduct more studies in order to validate components for each of the BCGs and utilize the full utility of BCG in conserving and managing landscapes. This should be conducted by selecting new sites within the UT for surveys and by repeating surveys at a subset of the 11 original sites. These studies will provide a means to calibrate and verify consistency of the BCG performance.
2. Studies should be initiated at UT sites using the fish, amphibian and vegetation conceptual BCGs.
3. Information from the BCG analysis should be incorporated in monitoring and evaluation reporting of the UT-Nairobi Water Fund with analysis of relationships of BCG with human activities, landuse types, conservation and restoration practices, etc.
4. With the implementation of conservation practices proposed for the UT over the next five years, follow-up surveys should be conducted where successful implementation has occurred to observe if there are corresponding responses in the associated BCG measurements.
5. There is a need to measure water quality parameters to complement biological monitoring measures particularly to assess the ecological conditions of sites under study. This is necessary where reference point or pristine sites are under study.

ACKNOWLEDGEMENTS

The participants in this effort invested significant time and commitment in the process. We are grateful for their tireless efforts in ensuring that the process was smooth.

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ACRONYMS

BCG - Biological Condition Gradient

NMK – National Museums of Kenya

KARU - Karatina University

CIAT – International Center for Tropical Agriculture

TNC – The Nature Conservancy

CMS - Catchment Management Strategy

WRMA - Water Resources Management Authority

TCA – Tana Catchment Area

USEPA – United States Environmental Protection Agency

UT – Upper Tana

UTNWF – Upper Tana Nairobi Water Fund

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CHAPTER ONE

MONITORING WETLAND HABITATS IN KENYA

1.1 Introduction

The need to manage waters resources in Kenya is well captured in the Water Act 2002, which established the Water Resources and Management Authority (WRMA) that has given the authority the national mandate to regulate and manage water resources. Key to management of water resources is establishment of monitoring and management initiatives, with each of the six major catchment areas developing a Catchment Management Strategy (CMS). The CMS borrows heavily from National Water Master Plan 2030 and its main objective is to support the management of the water resources environment and human behaviour in ways that achieve equitable, efficient and sustainable use of water for the benefit of all users (WRMA website, http://www.wrma.or.ke). The Tana Catchment Area (TCA) is one of the six catchment areas, with the other five being Lake Victoria North Catchment Area, Lake Victoria South Catchment Area, Rift Valley Catchment Area, Athi Catchment Area and Ewaso-Ngiro North Catchment Area.

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form that is easily understood by those entrusted with management of the environment (MENR 2012).

1.2 Rationale of adapting a usable biological index to assess and monitor wetlands in Kenya

A review of parameters used to assess and monitor wetlands shows relatively substantial amount of data exists for some wetlands in the country especially those experiencing significant levels of environmental degradations. Parameters studied comprise various measures of water quality and biological attributes. As observed, availability of this information has not been translated into prudent management of wetlands. One reason is this information is not in form that is easily understood by environmental and natural resources managers. Recently a number of efforts have been made to develop criteria to assess environmental conditions in wetlands in order to support their management and conservation in Africa (e.g. Graham et al 2004, Masese et al. 2009, Raburu & Masese 2012).

One such initiative is the development of the simplified version of the South African Scoring System, SASS now referred to as miniSASS, which uses macroinvertebrates to assess ecological health of streams (Graham et al 2004). The miniSASS version has a reduced taxonomic complexity of SASS by considering a few aquatic invertebrate 'groupings' that act as surrogates for the complete suite of SASS taxa (Graham et al 2004). The miniSASS attempted to satisfy the following requirements: (i) minimize the number of aquatic invertebrate groupings necessary to perform miniSASS, (ii) aquatic invertebrate groups should be easily identifiable, (iii) the method should be robust and produce results comparable to the full SASS technique, and (iv) be geographically widely applicable. In addition miniSASS is people-driven wetlands monitoring and restoration program. Following miniSASS example, a number of researchers in Kenya have adapted its criteria and developed Indices of Biological Integrity (IBI) as proposed by Karr (1981) to describe ecological conditions in wetlands based on macroinvertebrates (Masese et al., 2009, Raburu at al. 2009, Aura et al. 2010) and fish (Masese et al. 2009, Raburu and Masese 2012). The uptake and usage of IBI methods has been slow and this has been attributed to the complex nature in calculating the multiple metrics that are involved and interpreting them, which make them unusable by non-experts.

The history of assessing and monitoring water quality using biological indicators is over a century old. It started with the Saprobien System concept in early 1900 (Davis 1995) using benthic macroinvertebrates and planktonic plants and animals as indicators of organic loading and low dissolved oxygen (DO). It has been updated since its initial development and is currently used in several European countries, where the Saprobien System and lake trophic state classifications describe a response gradient (or response classes for lakes) to pollution from human and natural influences (e.g. Vollenweider 1968, Beck 1954; Pantle & Buck 1955). In summary these developments have led to today's biotic indices (Davis 1995). Some biotic indices use diversity indices based on information theory to describe changes in community structure, richness, and dominance (evenness) as a measure of pollution effects (e.g. Wilhm and Dorris 1966). The IBI integrates the concept of anchoring the measurement system in undisturbed reference conditions with the measurement of several indicators intended to reflect ecological components of composition, diversity, and ecosystem processes. It thus combines a conceptual model of ecosystem change in response to increasing levels of stressors with a practical measurement system.

It is obvious that environmental conditions in watersheds influence water quality in wetlands (Masese et al. 2012, Minaya et al. 2013). Therefore terrestrial biological indicators are important components of wetland assessment and monitoring programs because they have a utility to identify threats and causes of environmental degradation in watershed beyond just water pollution effects. Just like in wetlands, changes in terrestrial ecological components of species composition, diversity and ecosystems can be used to model their ecosystem change due to increasing levels of stressors. Therefore robust biological indices that are relevant to sustainable management of wetlands and associated watersheds should incorporate both wetlands and terrestrial biological indicators. The Biological Condition Gradient (BCG) that is grounded in the concepts of stress ecology articulated by Odum et al. (1979), Odum (1985), Rapport et al. (1985), and Cairns et al. (1993), describing "natural" conditions and the change in biological condition caused by stressors is a robust and appropriate index that can be designed to describe environmental conditions in both wetlands and watersheds. Initially BCG was developed based on USA state biologists' experiences with water quality management (Courtemanch et al. 1989; Yoder and Rankin 1995a; Davies et al. 2016), as well as the practical experience of a diverse group of aquatic scientists from different bio-geographic areas (Davies and Jackson 2006). In the following chapter, we introduce the BCG, describe its utilities in measuring ecological conditions and its potential for use in on assessing overall ecological condition of Upper Tana (UT) wetlands and watersheds.

CHAPTER TWO

BIOLOGICAL CONDITION GRADIENT

2.1 Introduction

The BCG is a conceptual, scientific framework for interpreting biological response to increasing effects of stressors on aquatic ecosystems (USEPA, 2016). The framework was developed based on common patterns of biological response to stressors observed empirically by aquatic biologists and ecologists from different geographic areas of the United States. The framework describes how nine characteristics (attributes) of aquatic ecosystems change in response to the increasing levels of stressors, from an "as naturally occurs" condition (e.g., undisturbed/minimally disturbed condition) to severely altered conditions. The BCG describes characteristics of aquatic ecosystems that are typically measured by USA's state water quality management programs that change in response to increasing levels of stress (see Table 1). The characteristics are defined as "attributes," and include aspects of community structure, organism condition, ecosystem function, and ecosystem connectivity.

Table 1: Revised ecological characteristics (i.e., attributes) used to develop the BCG (modified from Davies and Jackson, 2006 in USEPA, 2016)

Attributes	Description
I	Historically documented, sensitive, long-lived, or regionally endemic taxa
II	Sensitive (intolerant) taxa
III	Intermediate tolerant taxa
IV	Tolerant taxa
V	Non-native, intentionally or unintentionally introduced species
VI	Organism condition
VII	Ecosystem function
VIII	Spatial and temporal extent of human-caused effects
IX	Ecosystem connectance

The BCG framework can be considered analogous to a field-based dose-response curve where the dose (x-axis) represents increasing level of natural and anthropogenic stress, and the response (y-axis) represents biological condition. For example, high concentrations of certain metals, nutrients, or sediment can adversely impact or stress aquatic biota. Loss of suitable aquatic habitat or presence of aquatic invasive species can also adversely impact the aquatic biota expected for a specific water body. These stressors can cause aquatic ecosystems to change from natural conditions, including naturally occurring stress, and exhibit altered compositional, structural, and functional characteristics. The degree to which stressors affect the biota depends on the magnitude, frequency, and duration of the exposure of the biota to the stressors. Developing a BCG for a given system characterizes the general relationship between its stressors in total and a water body's overall biological condition. Stressors can include a wide range of independent or co-dependent causes such as water pollution, temperature, changes in water volume or flow, habitat alterations and modifications including wetland and terrestrial, exotic species introductions, or resource exploitation (e.g. overfishing). Multiple stressors are usually present, and thus, the stress x-axis of the BCG seeks to represent their cumulative influence as a Generalized Stress Axis (GSA), much as the y-axis generalizes biological condition. The x and y axes of the BCG serve as a framework to organize, relate, and help reconcile the mosaic of factors and interactions that exist, parts of which will be characterized and measured using biological, chemical, physical, and/or land use/land cover indicators.

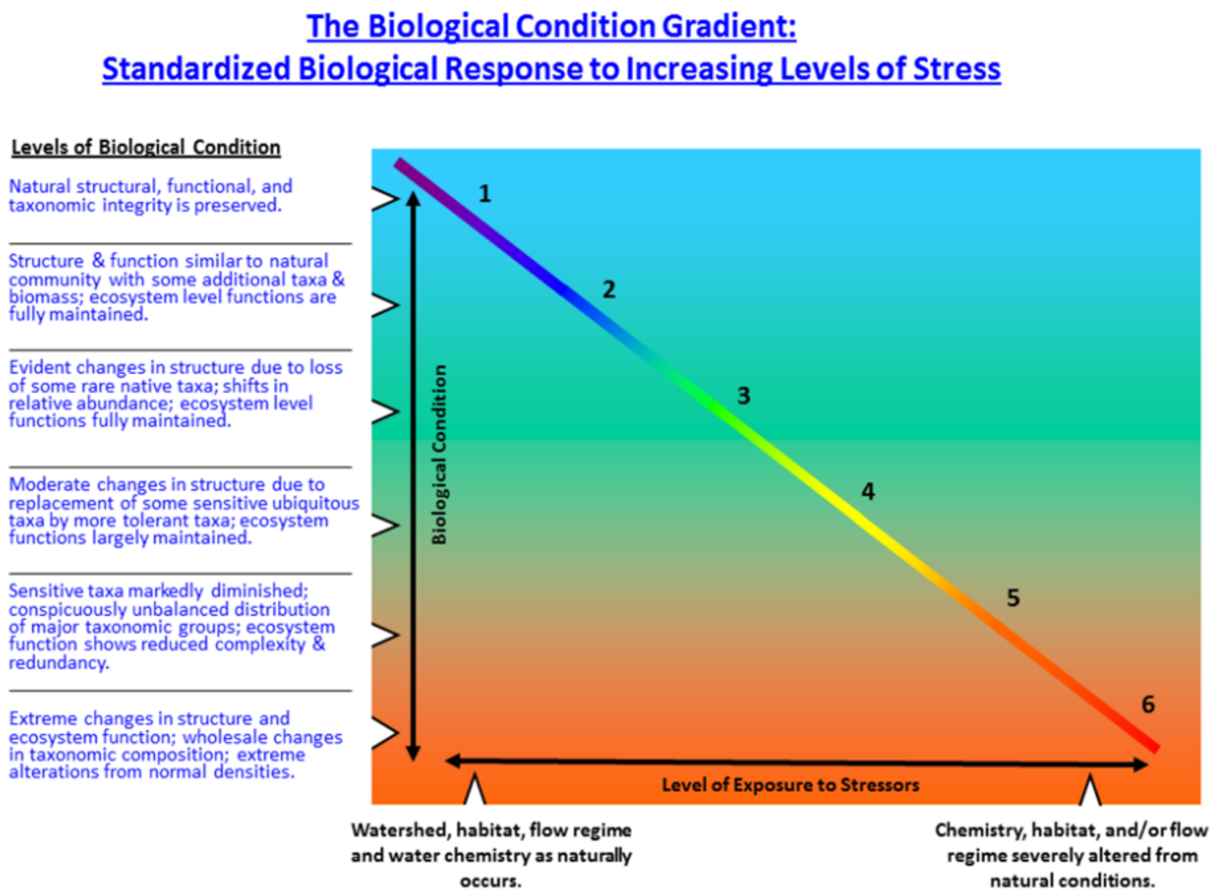

Figure 1: The Biological Condition Gradient, a descriptive model for interpreting changes in ecological condition in response to human disturbance (Davies and Jackson 2006; graphic courtesy of USEPA National Biocriteria Program). Note that the BCG is neither linear

As observed above, the BCG seeks to explain how biological entities respond to cumulative effects of stressors in an ecosystem, which are described as Generalized Stress Axis, GSA (Figure 2). As a theoretical construct, the GSA seeks to represent the cumulative stress that may influence biological condition. The conceptual GSA provides a framework to assist in development of as comprehensive and robust a quantitative stress gradient as possible to support BCG development. A well-defined, quantitative GSA, and the underlying data used to develop it, may serve as a nexus between biological and causal assessments, thereby linking management goals and selection of management actions for protection or restoration of ecosystems. It is promising that systematic testing of technical approaches to define and apply a GSA to BCG development has seen several studies conducted in pilot levels in USA (USEPA 2016). Opportunities in the future may include quantify a GSA for a specific geographic region and water body type throughout the world.

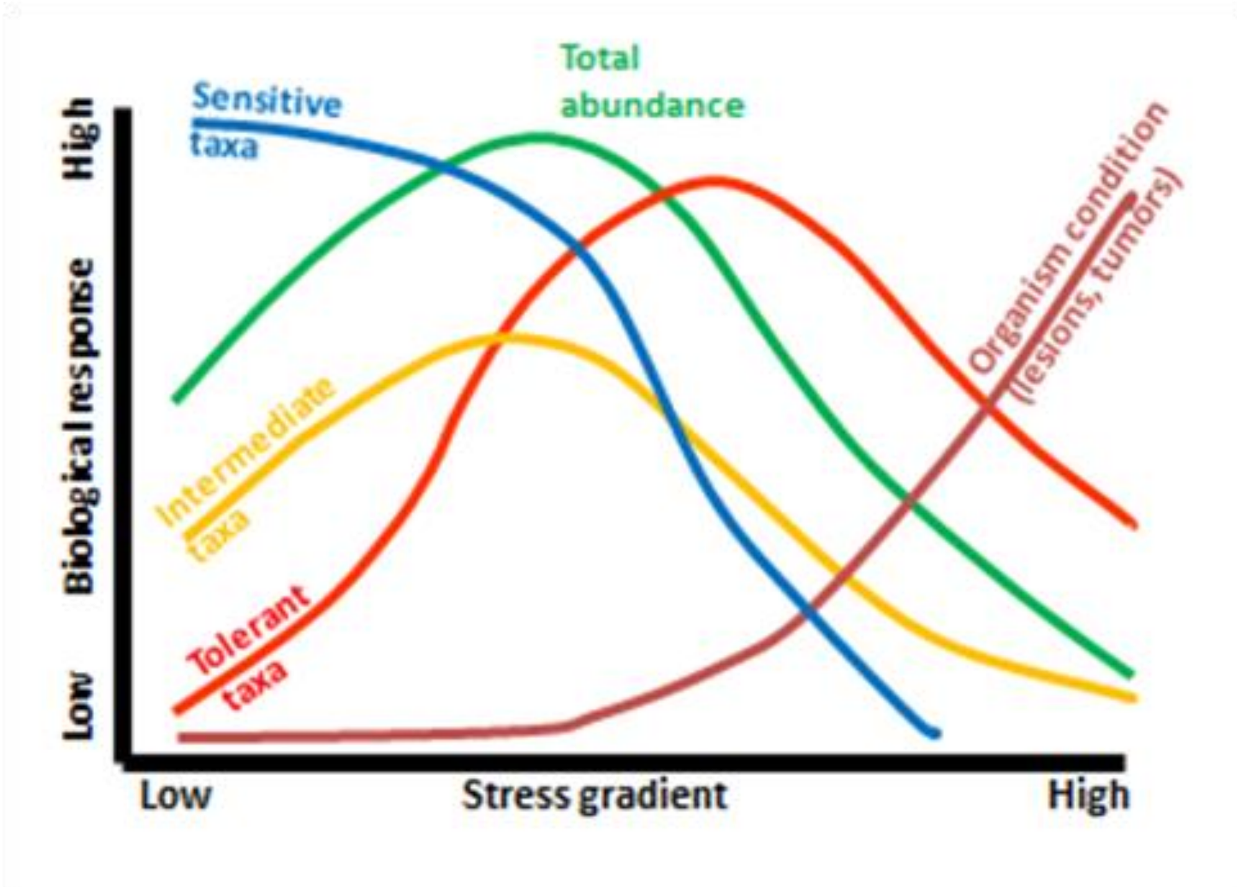

Figure 2: Hypothetical biological responses to multiple cumulative stressors

2.2 The utility and application of BCG

The BCG was conceived to help to make sense of the biological complexity encountered when one looks at the living characteristics of our waters (Davies and Jackson 2006; Figure1). Consistent differences in community structure and function are known to occur in aquatic assemblages as they are subjected to increasing levels of human presence and disturbance. The BCG provides an ecologically detailed description of commonly observed stages of change across six steps or tiers. **Tier I** describes the expected biological characteristics of naturally occurring aquatic assemblages where the human presence is small and relatively inconsequential, and provides the base condition from which the gradient is built. At the other end of the gradient, **Tier VI** describes the alteration of the aquatic assemblage for severely stressed and degraded waters. The BCG is built upon the observations, measurements, and experience of research scientists and water quality specialists across this gradient of natural to severe stress (Figure 2).

The model distills this information into an easily understood and readily communicated progression of altered biological condition in response to human disturbance. One does not have to fully understand all that the BCG describes about stress-induced changes among the ecological attributes on which it is built. In its simplest form, the BCG provides a readily accessible, six-part measuring stick to facilitate conversations about environmental values. It condenses the complexities of "data" by creating a bridge between scientific observations and their meaning. It helps even the untrained to interpret the implications of complex ecological data in relation to their own environmental values. To enter the conversation, it is enough to simply know in what BCG Tier a waterbody falls, and then to consider that condition in relation to one's hoped-for condition for that water. This information can be looked at in the context of a specific waterbody or at larger scales to look at the extent and distribution of conditions across a watershed. In summary, well-designed biological assessment organizes and assembles scientific evidence about ecosystem condition and the BCG provides a common translation tool that empowers anyone to participate in a conversation about what it means, what is of value, and if something needs to be done. Biological assessment is an indispensable tool if we hope to arrive at a full understanding of the value of our waters and ecosystem services they provide. While the BCG does not directly evaluate human benefits, the higher quality tiers generally represent waters that provide a full suite of ecosystem services including higher quantity and quality potable and domestic supply, higher value fishery resources, and quality more beneficial for agricultural and commercial uses.

From a management perspective, the tiers can provide helpful guidance. At this time and across many parts of the world, **Tier I** waters may be rare and, when found, certainly deserve a high level of protection**. Tier II** waters, while clearly affected by human presence, are similarly high quality but represent a condition where human use, land practices, and other effects are mitigated through good stewardship. **Tier III** waters are good quality and support many of the organisms and functional qualities of Tier I or II. **Tier IV** indicates a condition where there has been substantial disturbance and alteration in the ecosystem but where ecosystem functions are at least marginally maintained. Tier IV is often considered to be the minimally acceptable condition. **Tier V** is a condition where structure and function are deficient but where management actions can be expected to improve the ecological condition. **Tier VI** is severely altered and depending on the source and magnitude of disturbance may be a lower priority for recovery, may require significant resources for recovery, or may be determined unrecoverable. The management objective should not be to bring all waters to a Tier I or II condition or to manage waters upward or downward to only a minimally accepted condition (Tier IV). Rather, waters should be managed to optimize their ecological values relative to their landscape context, deployment of best management practices and sustainable use practices. Such a management approach should lead to general improvement along the gradient.

2.3 Tiers and attributes

Tiers: The BCG has been found to work well using a scale of six tiers (Table 2).While six tiers provide only a coarse classification of possible outcomes, it has been found to provide sufficient discrimination to be useful to water managers, planners, investors, users and consumers without becoming too complicated. This BCG model is built from information about nine ecological attributes (the original model used 10 attributes however practice has found that Attribute 2 (highly-sensitive, rare taxa) and Attribute 3 (intermediate-sensitive taxa) can be merged as

Sensitive taxa). Each attribute provides a key piece of information that informs the model where along the six tier gradient a waterbody belongs. Information or data to evaluate each tier may come in different forms. The BCG is fundamentally a knowledge-based model. That knowledge may come from a variety of sources including rigorous quantitative monitoring to qualitative surveillance methods to more informal observations. The BCG does not require a standardized method of data collection but rather encourages the use of any information with the discretion of the analyst to select among the available information to assign an attribute score. The number of attributes used and the quality of the sources will assist in determining the accuracy and certainty of a BCG decision.

Attributes: Each BCG tier is a compilation of information about the attributes. The attributes operate somewhat independently of each other. Evaluation of each attribute is not required in order to arrive at a decision, however the greater the number of attributes used in the model the higher the level of confidence in the decision. The overall model result is generally selected according to the lowest quality tier among the attributes, however expert judgement, such as the quality of information used for a particular attribute, should also be incorporated in making a final determination. Since the BCG is an integrated model, it does not immediately identify the presence or magnitude of any stress or disturbance. However, examination of the attributes can often point to presence of significant stressors and sources. The present model was built for flowing waters (perennial rivers and streams), however BCG models are in development for wetlands, lakes, estuaries and coral reefs (USEPA, 2016).

In conducting biological assessments, information is usually collected at the spatial scale of a site or reach and the temporal scale of a sampling event or site visit. Many of the attributes that make up the BCG are based on these scales, however the organisms present (or expected but not present) during a sampling event provide an integrated assessment of condition over the time at the site. Site scale attributes include aspects of taxonomic composition and community structure (**Attributes 1-5**), organism condition and ecosystem function (**Attributes 6 and 7**) usually respond at a larger spatial and longer temporal scale. At larger temporal and spatial scales, physical-biotic interactions (**Attributes 8 and 9**) are included because of their importance for interpreting smaller scale condition and evaluating long term impacts, recovery or restoration potential. Where sampling and observations are conducted using multiple sites and multiple sampling events the scale of a BCG determination can be extrapolated.

Table 2: Descriptions of the six BCG tiers and nine attributes (modified from Davies and Jackson, 2006).

General description of Tiers I-VI

I. The undisturbed ‘natural’ state (Tiers II-VI are measured as departures from this condition). Structure and function are as expected in an essentially undisturbed state for the region and habitat type; taxonomic completeness and ecosystem functions are fully maintained within the range of expected natural variability.

II. Most native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are maintained within range of expected natural variability.

III. Some changes in structure due to loss or recruitment of taxa, shifts in relative abundance

of taxa but sensitive taxa remain common and abundant; ecosystem functions are maintained through redundancy of organism function in the system. IV. Moderate changes in structure due to replacement of some sensitive taxa by more tolerant taxa, reproducing populations of some sensitive taxa are present, balanced distribution of expected major groups; ecosystem functions largely maintained through community redundancy. V. Sensitive taxa are markedly diminished or absent; conspicuously unbalanced distribution of major groups from natural state; organism condition may show signs of physiological stress; system function shows reduced complexity and redundancy; increased accumulation or export of organic matter. VI. Extreme changes in structure, wholesale changes in taxonomic composition with reduced taxa richness and prevalence of tolerant, opportunisitc taxa, acute disproportion of taxa densities and distributions; organism condition can be poor; ecosystem functions are severely altered, skewed, or missing.	
Attributes	**Tiers per attribute**
Attribute 1: Historically documented, sensitive, long-lived, some with complex life cycle, or regionally endemic taxa Taxa that are *historically documented* refers to those known to occur or have been supported in a water body or region according to historical records. This attribute was derived to cover taxa that are s*ensitive* or *regionally endemic taxa* have restricted, geographically-isolated distribution patterns or require access to different habitats, often due to complex life history requirements. They may be long-lived, late maturing, have low fecundity, have limited mobility, need access to multiple habitats, or require a mutualist relation with other species. They may be among listed endangered, threatened or special concern species therefore often having high conservation value. Predictability of occurrence is often low, and therefore requires documented observation. Recorded occurrence may be highly dependent on sample methods, site selection, and level of effort. The taxa that are assigned to this category require expert knowledge of life history and regional occurrence of the taxa. (fish, amphibians, are good candidates for Attribute 1	I. Occurring as predicted from documented records except for global extinctions II. Occuring as a sustainable populaton except for global extinctions III. Some taxa with reduced number or may be absent due to local extirpation IV. Taxa present in low abundance, or absent due to global, regional, or local extirpation V. Usually absent, if present, not as a sustaining population VI. Absent

taxa).	
Attribute 2: Sensitive taxa Sensitive taxa naturally occur as a relatively high proportion of population density, and may make up a large relative proportion of richness. Some of these species may occur at low density, thus their occurrence is dependent on sample effort. They may be stenothermic or cold-water obligates, with narrower range of tolerance for oxygen, pH or toxic substances. Many can be equilibrium species; populations maintained at a fairly constant level, slower development, longer life-span (so-called K-strategists). They might have specialized food resource needs or feeding strategies, and they are generally intolerant to significant alteration of the physical or chemical environment. They are often the first taxa observed to be lost from a community following moderate disturbance or pollution. (macroinvertebrates, amphibians and fish are commonly used for Attribute 2 taxa).	I. As predicted for natural occurrence, often making up greater than half of a group's density or biomass II. Present, often making up greater than half of a group's density or biomass, and may be increasingly abundant from the natural condition (a subsidy effect) III. Common and abundant; relative abundance and richness reduced IV. Some taxa present with reproducing populations maintained; some taxa replaced by functionally equivalent intermediate or tolerant taxa. V. Frequently absent or markedly diminished VI. Absent or very few
Attribute 3: Taxa of intermediate tolerance Taxa of intermediate tolerance commonly comprise a substantial portion of natural communities. They may be r-strategists (i.e., early colonizers with rapid turn-over times). Many have generalist or facultative feeding strategies enabling utilization of diverse food types. These species may show a positive response to increasing stress where resources increase and competition or predation from sensitive species decreases. They are often equally abundant in both reference and moderately stressed sites. They are intolerant of excessive pollution loads or habitat alteration. (macroinvertebrates and fish are commonly used for Attribute 3 taxa).	I. As predicted for natural occurrence often low density II. As naturally present with slight increases in abundance (subsidy effect) III. Often evident increases in abundance (subsidy effect) IV. Common and often abundant; relative abundance often greater than sensitive taxa V. May be dominant organisms in the community VI. May occur in low densities; richness of all taxa is low

Attribute 4: Tolerant taxa Tolerant taxa are present but comprise a low proportion of natural communities. Taxa often are tolerant of a greater degree of disturbance and stress than other organisms and are thus the "survivors" of pollution or habitat induced stress. They may increase in number (sometimes greatly) under severely altered or stressed conditions, and they may possess characteristics suited to persisting in conditions of organic pollution, hypoxia, or toxic substances. Tolerant taxa are usually comprised of opportunitstic species (short-lived with rapid generation cycles, so-called r-strategists). These are the last survivors in severely disturbed systems and may exhibit rapid colonization when freed from competition and predation by other organisms following an episode of stress. (macroinvertebrates and fish are commonly used for Attribute 4 taxa)	I. As predicted for natural occurrence often very low natural densities II. As naturally present with slight increases in abundance but still low density III. May be increases in abundance of functionally diverse tolerant taxa IV. May be common but do not exhibit significant dominance, may make up large proportion of community V. Often occur in high densities and usually dominant VI. Usually comprise the majority of the assemblage; often extreme departures from normal densities (high or low)
Attribute 5: Nonnative or intentionally introduced taxa: Taxa included in Attribute 5 are any taxa not native to that ecosystem or locale. Species introduced or spread from one region to another outside their naturally occurring range are termed non-native or non-indigenous, as are species introduced from other continents (alien species). Disease or parasite organisms occurring outside of their natural range may also be included as non-native taxa. This attribute represents both an effect of human activities and a stressor in the form of biological contamination. Although some intentionally introduced species are valued by segments of society (e.g., gamefish), these species can still be disruptive to native species (e.g. Rainbow Trout *Oncorhynchus mykiss*). Invasive species are those that become	I. Nonnative taxa, few if present, do not displace native taxa or alter natural structural or functional integrity II. Nonnative taxa may be present, but occurrence has a non-detrimental effect on native taxa III. Intentionally introduced nonnative and sensitive taxa may dominate some assemblages (e.g., trout or certain macrophytes) IV. Some replacement of sensitive native taxa with functionally diverse assemblage of nonnative taxa of intermediate tolerance V. Some assemblages (e.g., fish or

dominant in a community through displacement of native species and alteration of community structure and function (e.g., Rainbow Trout for fish and Water hyacinth, *Eichhornia crassipes* for vegetation). The BCG identifies maintenance of native taxa as an essential characteristic of Tier I and II conditions. The model allows for the infrequent occurrence of non-native taxa in these levels if those taxa do not displace native taxa and do not have a significant effect on natural structure and function. Increasing occurrence of non-native taxa altering community structure or function represents Tier III or IV. Extensive replacement of native taxa by tolerant or invasive, non-native taxa can occur in Tiers V and VI. (fish, amphibians, crustacea and plants are commonly used for Attribute 5 taxa; occurrence of non-native diseases or parasites may also be used)	macrophytes) are dominated by tolerant nonnative taxa VI. Often dominant; some species may be the only representative of some assemblages (e.g., plants, fish)
Attribute 6: Organism condition (especially of long-lived organisms). Organism condition is an element of ecosystem function, expressed at the level of anatomical or physiological characteristics of individual organisms. Organism condition includes direct and indirect indicators such as fecundity, morbidity, mortality, growth rates, and anomalies (e.g., lesions, tumors, and deformities). Some of these indicators are readily observed in the field and laboratory, whereas the assessment of others requires specialized expertise and greater effort to assess. (fish and amphibians are commonly used for Attribute 6)	I. Organisms appear physiologically sound; no anomalies or consistent with naturally occurring incidence and characteristics II. Organisms appear physiologically sound; no anomalies or consistent with naturally occurring incidence and characteristics III. Organisms appear physiologically sound; anomalies absent or very infrequent IV. Incidence of anomalies may be higher than naturally expected V. Organisms may exhibit physiological deficiencies. Biomass (e.g. condition factor of fish) may be reduced; anomalies increasingly common

	VI. Long-lived taxa may be absent or age classes missing; biomass reduced; anomalies often common; reproduction reduced or lost except for tolerant groups
Attribute 7: Ecosystem functions. Ecosystem function refers to processes required for normal performance of a biological system. The term may be applied to any level of biological organization. Immigration and emigration are functional processes at the population level. Examples of ecosystem functional processes are primary and secondary production, respiration, nutrient cycling, and decomposition. The term ecosystem function includes measures of both the interactions among taxa (e.g., food web characteristics) and energy and nutrient processing rates (e.g., trophic, energy and nutrient dynamics). These attributes are included in the BCG because ecologists universally recognize their fundamental importance. The level of effort required to directly assess ecosystem function is often beyond the means of many monitoring programs. Instead, monitoring programs rely on taxonomic and structural indicators to make inferences about functional status. For example, shifts in the primary source of food may cause changes in trophic guild indexes or indicator species. Attribute 7 also includes aspects of individual, population, and community condition. Altered interactions between individual organisms and their abiotic and biotic environments may generate changes in growth rates, reproductive success, movement, or mortality. These altered interactions are ultimately expressed at ecosystem-levels of organization (e.g., shifts from heterotrophy to autotrophy, onset of eutrophic conditions) and as changes in ecosystem process rates (e.g.,	I. All functions maintained within range of natural variability II. All functions maintained within range of natural variability III. Functions maintained through functionally redundant system attributes; observable changes in accumulation or export of organic materials. Functional shifts may indicate subsidy effects. IV. Functions maintained through functionally redundant system attributes; evidence of loss of efficiency by accumulation or increased export of organic material V. Apparent loss of some ecosystem functions manifested as increased export or decreased import of organic resources, and changes in energy exchange rates, apparent changes in primary or secondary productivity VI. Several to many functions show extensive and persistent alteration or loss.

photosynthesis, respiration, production, decomposition).	
Attribute 8: Spatial and temporal extent of detrimental effects. The spatial and temporal extent of stressor effects includes the near-field to far-field range of observable effects of the stressors on a water body. Such information can be conveyed by biological assessments provided the spatial density of sampling sites is sufficient to convey changes along pollution or other stress continuums, which provides a method for determining the severity (i.e., departure from the desired state) and extent (i.e., distance over which adverse effects are observed) of an impairment from one or more sources. Spatial sampling design is a consideration in biological evaluations and is keyed on providing sufficient data to evaluate the spatial and temporal effects of stressors. Alternatively, spatial analysis of conditions causing stress effects (e.g. land use, habitat alteration, pollution sources) may be used to extrapolate site assessments to larger scale.	I. A natural disturbance regime is maintained II. Change limited to small patches and short duration III. Limited to the reach scale and/or limited to within a season IV. Some detrimental effects may be detectable beyond the reach scale or may include more than one season V. Detrimental effects extend to multiple reaches leaving only refuge areas of adequate conditions; effect can extend across multiple seasons VI. Detrimental effects widespread and across multiple seasons; may severely limit refugia and recolonization sources within the catchment
Attribute 9: Ecosystem connectance. Connectance refers to the access or linkage (in space/time) to materials, locations, and conditions required for maintenance of populations of aquatic life. It is the opposite of fragmentation and is necessary for metapopulation maintenance and natural flows of energy and nutrients across ecosystem boundaries. Connectivity can be expressed by the presence of certain species that depend on the connectance within an aquatic ecosystem to fully complete their life cycles and thus maintain their populations. Ecosystem connectivity can often be evaluated through spatial analysis if information is available to indicate disconnects in the system (examples of human caused barriers include dams,	I. Ecosystem well connected in space and time, at least annually, with only natural barriers present. II. Ecosystem connectance is unimpaired, some barriers may be present but there is sufficient access to habitats to maintain all species. III. Some loss of connectance but there are adequate local recolonization sources and negligible effect to system structure and function IV. Some loss of connectance with

dewatered habitat, heat or pollution barriers). Diadromous species or other highly mobile or obligate migratory species are commonly used biological indicators for Attribute 9, or spatial analysis may be used (e.g. presence of dams or other mapped barriers or disconnected habitats)	subsequent loss of some species or life stages, colonization sources and refugia still exist within the catchment for most species V. Significant loss of ecosystem connectance is evident and numerous, interrupting regular organism movement; recolonization sources disconnected for some taxa, some taxa excluded VI. Severe loss of ecosystem connectance in at least one dimension (i.e., longitudinal, lateral, or temporal) severely restricting movement; lowering reproductive success of some taxa; excluding some taxa or isolating some populations; frequent failures in reproduction and recolonization

CHAPTER THREE

PROVISIONAL BCG: A CASE STUDY FOR MACROINVERTEBRATES OF UPPER TANA

Gilbert Kosgei and George G. Ndiritu

3.1 Introduction

Aquatic macroinvertebrates are among the most preferred biological indicators of environmental health. This is due to their low mobility, relatively long residence times and differential sensitivity to environmental changes (Fennessy *et al.* 2004). They are easy to use and produce defensible evidence of environmental degradation (Klemm *et al*. 2003, Uwadiae 2010). A number of macroinvertebrate attributes are used to infer the quality of water and they include presence or absence of some species, percentages of sensitive and tolerance species to changes in environmental conditions, species abundances, evenness and diversity (Ziglio & Siligardi 2006).

In Kenya and the whole of Africa Continent there have been numerous efforts of using macroinvertebrates to assess and monitor environmental conditions in wetlands (e.g., Graham et al 2004, Raburu at al., 2009). The South Africa Scoring System (SASS), also simplified version miniSASS is used to assess ecological health of streams using macroinvertebrates (Dickens & Graham 2002, Graham et al 2004). In Kenya, a number of local researchers developed Indices of Biological Integrity (IBI) to describe ecological conditions in wetlands based on macroinvertebrates (Masese et al., 2009, Raburu at al., 2009, Aura et al. 2010). Meanwhile the uptake and usage of IBI methods have been low and this have been attributed to the complex nature in calculating and interpreting them, which make them unusable by non-experts.

3.2 Approach

Development of provisional BCG for macroinvertebrates for Kenya comprised three major phases: (i) compiling and summarizing studies of macroinvertebrates studies in Kenya, (ii) holding a workshop of macroinvertebrates experts to establish using their knowledge and experience where specific taxonomic group are likely to occur along a gradient of environmental conditions, and (iii) carrying out a rapid reconnaissance survey of macroinvertebrates in sites with varying degree of disturbances in the UT. As noted substantial number of studies have been carried in Kenya and were heavily relied on during the development of macroinvertebrates BCG for the UT included (e.g. Cumberlidge 1981, Mathooko and Mavuti 1992, Mathooko 2002, Dobson et al. 2002, Mwaura et al. 2002, Smart 2002, Ndaruga et al. 2004, Muli 2005, Kibichi et al. 2007, Kundu 2007, Ochieng et al. 2007, Raburu et al. 2009, Masese et al., 2009a,b; 2012; Nyakeya et al. 2009, Aura et al. 2010, 2017; Ojunga et al. 2010, Raburu & Masese 2012, Minayaet al. 2013, Ngothe et al. 2013, Kilonzo et al. 2014, Mbaka et al. 2014a,b; MErimba et al. 2014, Odhiambo & Mwangi 2014, Gichana et al. 2015, Orwa et al. 2015, Minoo et al. 2016, Kundu 2017). This information was complemented with experts' knowledge and experience and thereafter enriched with a reconnaissance survey of macroinvertebrates survey in UT.

It is evident from the above literature review that enough information exists on macroinvertebrate assemblages and their associated ecological conditions. Pristine rivers and streams generally have a variety of species with representatives of nearly all insect orders. These include a high diversity and relative abundance of insects in the taxonomic orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) otherwise commonly referred to as EPT taxa. Pollution tends to eliminate sensitive taxa such as EPT. On the other hand, degraded habitats were dominated by certain taxa representing pollution-tolerant organisms such as earthworms (Tubificidae), midge fly larvae (Chironomidae), crane fly larvae (Tipulidae), and non-bottom dwellers such as diving beetles (Dytiscidae) and water boatmen (Corixidae). Pollution and disturbance affect the physical, chemical, and biological conditions of habitats, which cause a reduction in the diversity and abundance of sensitive taxa. They may also lead to changes in community structures such as a lower percentage of EPT taxa and a higher percentage of pollution tolerant species. Macroinvertebrates indicate habitat impacts even those not detectable by traditional water quality assessments. Using information compiled a provisional macroinvertebrates BCG was developed for the UT (Table 3). In addition a list of macroinvertebrates found in UT and their expected population responses to increasing stress levels is given as Appendix 1.

Table 3: Macroinvertebrate BCG for the UT

Note: Five attributes were selected and used to describe the six BCG tiers. The attributes selected were **Attribute I**: Historically documented, sensitive, long-lived, or regionally endemic taxa, **Attribute II:** Highly sensitive taxa**, Attribute III**: Intermediate tolerant taxa, **Attribute IV**: Tolerant taxa, **Attribute V:** Non-native or intentionally introduced species.

Resource Condition Tiers (BCG)	**Macroinvertebrate attributes**
1 ***Natural or native condition***	**I: *Historically documented, sensitive, long-lived, or regionally endemic taxa:*** Two afro-montane species *Platycypha amboniensis* (The Montane or Kenya jewel) and *Notogomphus maathaiae* (Maathai Longlegs) are endemic to Kenya and specifically the UT watershed; where they were found in Rivers Amboni and Thegu. Maathai Longlegs was collected from Gatamaiyu and Kikuyu Escarpment forests within the Aberdares. A third species listed as vulnerable in Kenya is the damselfly *Pseudagrion bicoelurans* (Giant Sprite) and restricted to East Africa (Clausnitzer et al. 2012) and prefer forested streams above 2000 metres above sea level. All the three species prefer pristine environments.

Resource Condition Tiers (BCG)	Macroinvertebrate attributes
	II: *Sensitive taxa:* The following taxa are sensitive and intolerant to siltation/sedimentation in rivers and streams. Ephemeroptera Plecoptera Trichoptera (EPT) as a group are expected to show a dominant presence this Tier. In the UT they were well represented by Ephemeroptera or Mayflies group of Trichorythidae, Dicercomyzidae, Ephemerythidae, Leptophlebiidae, Oligoneuriidae, Prosopistomatidae; Trichoptera or caddisflies Lepidostomatidae, Leptoceridae; Plecoptera or Stoneflies: Perlidae. Also the Lepidoptera or Aquatic moths, Crambidae is known to prefer pristine habitats. Presence of highly sensitive species under this attribute (Plecoptera: Perlidae) is a strong indicator of Tier 1. **III: Intermediate Tolerant taxa:** While intermediate tolerant taxa may occur in low relative abundance in Tier 1, no tolerant species was found as an indicator of Tier 1 **IV: Tolerant taxa:** While tolerant taxa may occur in low relative abundance in Tier 1, no tolerant species was found as an indicator of Tier 1. **V: Non-native or intentionally introduced species:** Non-native taxa should not be found in this Tier.
2 ***Minimal changes in structure of the biotic community and minimal changes in ecosystem function***	**I: *Historically documented, sensitive, long-lived, or regionally endemic taxa:*** The three species The Montane or Kenya jewel, Maathai Longlegs and Giant Sprite are also likely to be found in this Tier. **II: *Sensitive taxa:*** The following taxa are sensitive and intolerant to siltation/sedimentation in UT rivers and streams. They comprise the Ephemeroptera Plecoptera Trichoptera (popularly known as EPT) and are expected to dominate. In the UT they are well represented by Ephemeroptera or Mayflies group of Trichorythidae, Dicercomyzidae, Ephemerythidae, Leptophlebiidae, Oligoneuriidae; Trichoptera or Uncased-Caddisflies of Lepidostomatidae, Polycentropidae; Trichoptera Cased-Caddisflies's Leptoceridae, Plecoptera or Stoneflies: Perlidae. Also the Lepidoptera or Aquatic moths, Crambidae is known to prefer pristine habitats. **III: Intermediate tolerant taxa:** The following taxa tolerate moderate changes in water quality are likely to be found together with the above high sensitive taxa. They include Trichoptera or Uncased-Caddisflies of Philopotamidae, Dragonflies: Coenagrionidae, Lestidae, Chlorocyphidae, Libellulidae, Gomphidae, Macromiidae and Aeshnidae. Other taxa are Mayfly

Resource Condition Tiers (BCG)	Macroinvertebrate attributes
	families of Heptageniidae, Baetidae. **IV: Tolerant taxa:** While tolerant taxa may occur in low abundance in Tier 2, no tolerant species was found as an indicator of Tier 2. **V: Non-native or intentionally introduced species:** No taxa was found to represent this Tier. Non-native species may occur in Tier 2 but only as an incidental occurrence
3 ***Evident changes in structure of the biotic community and minimal changes in ecosystem function***	**I: *Historically documented, sensitive, long-lived, or regionally endemic taxa:*** No taxa is known to fit this Tier. The three species The Montane or Kenya jewel, Maathai Longlegs and Giant Sprite may occur in this Tier **II: *Sensitive taxa*:** The EPT group is expected to be present though in moderate to lower populations relative to Tiers 1 and 2. Groups expected are Ephemeroptera or Mayflies group of Trichorythidae, Dicercomyzidae, Ephemerythidae, Leptophlebiidae, Oligoneuriidae; Trichoptera Cased-Caddisflies's Leptoceridae, Lepidostomatidae, Polycentropidae. Plecoptera or Stoneflies: Perlidae and the Lepidoptera or Aquatic moths, Crambidae may be absent or much reduced.. **III: *Intermediate Tolerant taxa*:** The following taxa tolerate moderate changes in water quality are likely to be found together with the above high sensitive taxa with increasing relative abundance. They include Dragonflies (e.g., Libellulidae, Gomphidae, Macromiidae, Aeshnidae), Damselflies (Coenagrionidae, Lestidae, Chlorocyphidae), Trichoptera or Uncased-Caddisflies of Hydropsychidae, Philopotamidae particularly *Chimarra ambulans* or Finger-net Caddisflies, Hydropsychidae; Crane fly larvae (Tipulidae), and the Mayfly family of Heptageniidae, Baetidae; Coleoptera (Helodidae, Hydraenidae, Psephenidae and Elmidae); Diptera (Athericidae, Blepharoceridae) **IV: *Tolerant taxa*:** Tolerant species likely to occur more frequently are True flies (including Tabanidae, Chironomidae), Planaria, some crabs, and Water Scavengers Beetles (Hydrophilidae). **V: *Non-native or intentionally introduced species*:** *Procambarus clarkii* or Cray fish may occur in this Tier.
4	**I: *Historically documented, sensitive, long-lived, or regionally endemic taxa:***

Resource Condition Tiers (BCG)	Macroinvertebrate attributes
Moderate changes in structure of the biotic community and minimal changes in ecosystem function	No taxa is known to fit this Tier. **II:** ***Sensitive taxa****:* The EPT group is expected to be present though in reduced numbers. Groups expected are Ephemeroptera and certain Trichoptera **III:** ***Intermediate Tolerant taxa*****:** The following taxa with moderate tolerance to changes in water quality are likely to be the most dominant. They include Dragonflies (e.g., Libellulidae, Gomphidae, Macromiidae, Aeshnidae), Damselflies (Coenagrionidae, Lestidae, Chlorocyphidae), Trichoptera or Uncased-Caddisflies of Hydropsychidae and the Mayfly families of Heptageniidae and Baetidae. **IV:** ***Tolerant taxa*****:** Tolerant species are likely to occur occasionally and naturally are True flies or Tabanidae, Planaria, some crabs, Water Scavengers Bettles (Hyrophilidae), Hydropsychidae, midge flies (Chironomidae), Horse flies (Tabanidae), Worms (Oligochaeta, Tubificidae), Gastropoda (Thiaridae, Lymnaeidae, Planorbidae), Leeches (Hirudinae), Crane fly larvae (Tipulidae), True flies (Diptera), Diving Beetles (Dytiscidae), and Water Boatmen (Corixidae). This group of taxa are likely to occur in equal population with intermediate tolerant taxa. **V:** ***Non-native or intentionally introduced species*****:** *Procambarus clarkii* or Cray fish is likely to occur in this Tier.
5 ***Major changes in structure of community***	**I:** ***Historically documented, sensitive, long-lived, or regionally endemic taxa:*** No taxa is known to fit this Tier. **II:** ***Sensitive taxa****:* The EPT group is expected to be absent in this Tier or only as an incidental occurrence. **III:** ***Intermediate Tolerant taxa*****:** A number of taxa of Dragonflies (e.g., Libellulidae, Gomphidae, Macromiidae, Aeshnidae), Damselflies (Coenagrionidae, Lestidae, Chlorocyphidae), and the Mayflies family of Heptagenidae and Baetidae might be present but in extremely low populations. **IV:** ***Tolerant taxa*****:** This Tier is likely to be dominated by tolerant species such as True flies (Diptera, Tabanidae), Planaria, some crabs, Water Scavengers Bettles (Hydrophilidae), midge flies (Chironomidae), House flies (Muscidae), Worms (Oligochaeta, Tubificidae), Gastropoda (Thiaridae, Lymnaeidae, Planorbidae), Leeches (Hirudinae) and Diving Beetles (Dytiscidae), and Water Boatmen (Corixidae).

Resource Condition Tiers (BCG)	**Macroinvertebrate attributes**
	V: ***Non-native or intentionally introduced species*****:** *Procambarus clarkii* or Cray fish is unlikely to occur in this Tier..
6 ***Severe changes in structure of the biotic community and major loss of ecosystem functions***	**I:** ***Historically documented, sensitive, long-lived, or regionally endemic taxa:*** No taxa is known to exist this category. **II:** ***Sensitive taxa****:* The EPT group is expected to be absent in this kind of ecological conditions. **III:** ***Intermediate Tolerant taxa*****:** No taxa are expected under this category or only as incidental occurrences. **IV:** ***Tolerant taxa*****:** This Tier is likely to be dominated by tolerant species such as True flies (Diptera, Tabanidae), midge flies (Chironomidae), House flies (Muscidae), Worms (Oligochaeta, Tubificidae) and Leeches (Hirudinae). **V:** ***Non-native or intentionally introduced species*****:** No non-native taxa is known to tolerate these ecological conditions.

3.3 Limitations

The provisional macroinvertebrates BCG was primarily developed for first to third order streams. Therefore it is unsuitable for standing wetlands and large rivers. There are plans in the near future to develop another for monitoring standing wetlands such as marshes, swamps, man man-made dams and water pans.

CHAPTER FOUR

PROVISIONAL BCG: A CASE STUDY FOR BIRDS IN UPPER TANA

P. Njoroge, F. Juma, V. Onyango and E. Mlamba

4.1 Introduction

Birds are often considered as a useful indicator group, either for monitoring environment change (Furness & Greenwood 1993, Bryce et al 2002) or for assessing biodiversity importance (e.g. Stattersfield 1998). Their usefulness is derived from their relative ease to observe, count and identify (Pomeroy 1992). Many bird species respond strongly to structural characteristics of the habitats they live in, e.g. the extent of forest degradation will have a corresponding impact on the species diversity and abundance. Though these impacts may be detected by simple lists, densities give a deeper insight of the ecological interactions at individual or community scale (Opdam & Wiens 2002). Bennun et al (1996) developed a simple classification system for East African Forest birds that goes further than species list and detects subtle differences between forest avifaunas in both space and time. The classification system has three categories:

I. Forest specialists- which are the ‘true’ forest birds characteristic of undisturbed forest,
II. Forest generalists- which may occur in undisturbed forest but are also regularly found in forest strips, edges and gaps. They are likely to be commoner there and in secondary forest than in the interior of intact forest,
III. Forest visitors-which are often recorded in forest, but are not dependent upon it. They are almost always more common in non-forest habitats, where they are most likely to breed.

Using proportions of birds in each category in the classification system can be usefully applied to develop indices that indicate various forest conditions (Furness & Greenwood 1993, Bryce et al 2002, Bennun et al 1996). We use this in our attempt to build a BCG for birds in this section. Further development of the BCG could incorporate feeding guild categories into the abundance data for deeper understanding of effects of habitat management on birds since different guilds respond differently to particular structural changes (Plumptre & Owiunji 1998).

Use of birds to monitor highland riparian habitats in Kenya is rare, though there are known species whose presence is tied to the condition of upland streams and rivers e.g. African Black Duck *Anas sparsa leucostgma* which prefers mountain streams in suitable forest habitats (Zimmerman et al 1996). The species is however not ideal for monitoring of mountain streams because it occurs in naturally low numbers. Annual Waterbird counts have been used in Kenya to monitor the long term condition of major rift valley lakes since 1991. The counts have provided the baseline data on bird populations and their fluctuations permitting the identification of species or groups in longterm decline (Bennun and Nasirwa 2000). Some of the fluctuations have been related to ecological changes in the lakes (Bennun 2001).

4.2 Approach for developing Provisional BCG for birds

Seven attributes were use to develop the BCG for birds and include:

Attribute 1. Historically documented sensitive/endemic taxa. For the Upper Forest specialists species (FF species) are the ideal species to help describe this attribute. Their characteristic is such that they are require undisturbed forest, but may persist albeit in lower numbers and diversity in secondary forest and forest patches (Bennun *et al* 1996). There are 43 forest specialist bird species that are known to occur in the Upper Tana forests (Mt Kenya and Aberdares). Using our expert knowledge we would propose that a site with over 80% .i.e. 34 out of 43 forest species be designated as Tier 1. Any deviation from this reference condition is therefore used to designate the other biological condition gradient tiers.

Attribute II: Sensitive (Intolerant) Taxa. For Tier I Forest specialists would still occur but in lower abundances and diversity (50%). The habitat will be dominated by forest generalists (F species). These species though they may occur in undisturbed forest they are more abundant in secondary forest, forest strips, edges and gaps (Bennun *et al* 1996). They typically breed in the forest.

Attribute III: Taxa of intermediate tolerance (forest generalists or F species). Under Tier 1 FF species may occur (less than 5%). Forest generalists (50%) more common here than in intact forest. Forest visitors occur in equal proportions to forest generalists.

Attribute IV. Tolerant taxa (forest visitors or f species). These species are often recorded in forests but are not dependent on it. Breeding is almost always outside of the forest (Bennun *et al* 1996) and are most common in non-forest habitats.

Attribute V: Non-native or introduced species**.** There are not that many invasive bird species in Kenya. If they occur in the reference condition Tier 1, they generally do not displace or out compete native species. They are more abundant and common in non-forest habitats.

Attribute VII: Ecosystem Functions. All ecosystem services including provisioning, regulating and supporting services are maintained within the natural range of variability, under the reference Tier

Attribute IX. Ecosystem Connectance. The presence of forest dependent species should indicate connectance both in space and time at least annually. However caution should be taken considering other ecological factors may heavily influence this attribute including distance from large block of forest and bird species ability to disperse

Based on the outcome of a preliminary survey of birds in the Upper Tana and our expert knowledge a probable ecological attribute versus condition tier matrix for UT was developed (Table 4), with expected response of some birds to environmental stress provided in Appendix 2.

Table 4: BCG for birds

	BIOLOGICAL CONDITION GRADIENT TIERS					
Ecological Attributes	**Tier 1: Natural or native condition Reference condition**	**Tier II: Few changes in Biotic community and minimum changes in ecosystem function**	**Tier III: Evident changes in structure of the biotic community and some changes in ecosystem function**	**Tier IV: Moderate changes in structure of bird community**	**Tier IV: Major changes in structure of bird community**	**Tier VI: Severe changes in structure of the biotic community and major loss of ecosystem functions**
I. Historically documented sensitive/endemic taxa	Over 80% of FF species (forest specialist) occur. Some endemics may occur (e.g. Abbott's and Kenrick's Starling)	Viable populations (over 50%) of FF species occur	FF species still present but probably not breeding. Difficult to distinguish Tier III and IV. F species (generalists)dominant	Occasional records of FF species (less than 5%). F species still dominant. Records of FF species not viable populations	FF Species completely disappear. Note because of the dispersal ability of birds vagrant FF species may be recorded on rate occasions	Ecosystem function due to FF species completely disappear
II. Sensitive (Intolerant) Taxa (Forest Specialists or FF species)	FF species present (over 50%). F species (generalists) dominant or in equal numbers	F species dominate but f species increasingly abundant.	A few F species still occur but f species dominate	A few F species still occur but f species dominate	No FF or F species (except as vagrants). f species and non forest species dominate	No FF or F species (except as vagrants). f species and non forest species dominate
III. Taxa of intermediate tolerance(forest generalists or F species	FF species may occur (less than 5%), Forest generalists (50%)common but forest visitors occur in equal proportions	F species dominate but f species evidently abundant.	f species dominate and evidently abundant.	f species common and may be more abundant than F species	Species richness of all groups is low. Extreme low densities	Bird species composition and abundance very low
IV. Tolerant Taxa (forest visitors or f species)	Naturally low densities, vagrants or entirely absent	Small increases in abundance but still naturally low densities	Subtle increases evident but no dominance	Indistinguishable with tier 3	Forest visitor Species dominate (up to 100%). No forest generalists, and certainly no forest specialists	Forest visitors completely dominate. Ecosystem functions completely lost
V. Non-native or introduced species. e.g. House sparrows	If present they do not displace native taxa	Present but occurrence not detrimental to native taxa	Evident replacement of native taxa or equal cohabitation	Similar to Tier 3 but higher abundance of non-native Taxa	Native taxa displaced. Non-native completely dominate	Similar to tier V

	BIOLOGICAL CONDITION GRADIENT TIERS					
Ecological Attributes	**Tier 1: Natural or native condition Reference condition**	**Tier II: Few changes in Biotic community and minimum changes in ecosystem function**	**Tier III: Evident changes in structure of the biotic community and some changes in ecosystem function**	**Tier IV: Moderate changes in structure of bird community**	**Tier IV: Major changes in structure of bird community**	**Tier VI: Severe changes in structure of the biotic community and major loss of ecosystem functions**
VII. Ecosystem Functions	All are maintained within the natural range of variability	All are maintained within the natural range of variability	Apparent loss of some ecosystem services	Indistinguishable with tier 3	Many functions disrupted. Evident through low or absent functional groups e.g insectivores	All ecosystem functions disrupted and probably absent
IX. Ecosystem Connectance. (NB: Other ecological factors may heavily influence this attribute including distance from large block of forest and bird species ability to disperse	System is highly connected in space and time at least annually. Evident by the high presence of forest dependent species	Ecosystem well connected. Habitats connected. Forest specialist species present.	Evident loss of connectance. Few forest specialist species	Some loss of connectance. Similar to tier 3.	Significant loss of ecosystem connnectance. No forest specialists but vagrants may occur	No ecosystem connectance at all. No forest specialist species except vagrants

4.3 Limitations of the proposed BCG

Bird abundance and diversity will respond to many ecological factors and their complex interactions; including habitat heterogeneity and food availability. For example distance from a large forest block will influence the diversity of birds with sites close to a large forest block having a high diversity of species than sites located far from the block. Therefore a site may be severely degraded but still have a high diversity of bird species, due to enhanced connectivity to suitable habitats and indicating the general condition of the larger watershed area. Other factors that need to be considered when using birds as indicators of habitat condition include structural heterogeneity of the agricultural landscape, the occurrence of a large species pool of widespread open-country birds that have always occupied the vast savannah woodland and grassland areas in eastern Africa and bird dispersal ability/mobility.

In our proposed BCG the presence of some avian endemics is not usually a good determinant of condition or ecological attribute. An endemic species would have to be also a forest specialist species in order for it to be used to predict a natural state. For example, Hinde's Babbler which is endemic to the Upper Tana region is not a forest species and is actually at home in intensively cultivated landscapes with some scrub and therefore not a good indicator of habitat condition.

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CHAPTER FIVE

PROVISIONAL BCG FOR VEGETATION OF THE UPPER TANA WATERSHED

Peris Kamau, Taita Terer and George G. Ndiritu

5.1 Introduction

The vegetation of highlands of Upper Tana River watershed and neighboring areas has been described in several publications including those of Hedberg (1951), Lebrun (1956), Greenway (1973), Lind & Morrison (1974), White (1983), Trapnell & Brunt (1987) and Beentje 1988 & 1990). Lillesø et al (2011) used most of these classifications to provide a reviewed and more detailed potential vegetation zonation of the region, which acknowledged presence of sub-plant communities within the larger groups. More specifically, Schmitt (1991) and Bussmann (1994) provided more detailed vegetation communities for Aberdares and Mt Kenya, respectively. The vegetation classifications provided are majorly based on plant community assemblages (phytosociological), determined by dominant species, altitudinal changes, edaphic attributes, as well as syntaxonomical groups.

The vegetation in the Upper Tana watershed plays an important role in maintaining water quality and quantity, providing areas where runoff water and sediment are stored and naturally filtered. However, since the 1970s, the unprotected forests and woodlands including those in steep hillsides, rivers and areas of wetlands have been converted to agriculture. Majority of the forests area from lower edges in woodlands and up to the afromontane zones have been converted to farmlands growing tea, coffee and food crops, safe for the protected national parks and forests.

According to Muchena et al (2012), over 50% of the region has been converted to agriculture. In particular, the dominant cover is the rainfed herbaceous crop (33.24%) where maize and other herbaceous crops and livestock farming are practiced. The second dominant land cover type is the rainfed shrub crop (14.68%) representing the tea and coffee shrubs. Following heightened agroforestry campaigns, however, these regions have witnessed massive tree planting mainly using the fast growing species such as *Grevillea* and *Eucalyptus* species among the coffee or tea plantations, as well as along boundaries and riparian ecosystems usually with detrimental effects.

Land use type and vegetation cover changes have been documented between 1990 and 2010 (Kamau & Wasonga, 2015). Between the year 1990 and 2000, the total forest size declined by 23% owing to anthropogenic pressures. However between the year 2000 and 2010 there was an increase of 31% forest. The highest decline in forest cover was recorded in Aberdares (7.9%) between 1990 and 2000, with forests in Mt. Kenya showing a decline of 3%. Loss and degradation of the natural vegetation were well reflected on increased surface runoffs, sediment transport and deposition with negative effects on aquatic biota as well as reduced capacity of water reservoirs to store water. Meanwhile the ecological conditions of watershed can be reliably assessed by documentation both terrestrial and wetland vegetation. In both cases pristine environmental are likely to be occupied with natural vegetation communities while areas under different levels of degradation are likely to be occupied by vegetation communities indicating those conditions (Mligo 2017, Handa at al. 2012).

It is obvious that the ecological conditions of watersheds are directly linked with water quality in wetlands as such any serious conservation and interventions activities must also consider the restoration of watersheds. A quick assessment of vegetation communities in the catchment is enough to inform the environmental conditions of the watershed. Riparian habitats are botanical hotspots, due to habitat heterogeneity provided by unique characteristics along streams, river banks, floodplains and associated wetlands (Ledec 1987, Maingi & Marsh 2006), that underpins their importance in supporting and maintaining ecological processes and functions in landscapes (Hitoshi & Toshikazu 2008). For instance forests are key sources of food, cover, and water, and serve as migration routes and habitat connectors for a variety of wildlife. They also help control water pollution, reduce erosion, mitigate floods, and increase groundwater recharge. However, forests systems have become increasingly susceptible to both natural and human disturbances as cumulative pressures from changing land use and climate alter them and consequently the hydrological regimes.

Some group of plants species especially bryophytes, lichens and ferns react differently to change in environmental conditions and therefore are a good for monitoring forest quality and level of disturbance. They play major ecological roles in forests processes and their occurrences are associated with different ecological conditions. Other species in these specialists group show narrow range of habitat requirements and as such are highly affected by slight alteration of their preferred local habitats. Species patterns in different localities are a good indicator of how species respond to different conditions/stress occasioned by human or natural disturbances as well as natural influences. Such species will be used as indicators of magnitude of disturbance in different wetlands and terrestrial study sites. Some specific plant species especially herbaceous layer show a clear habitat differentiation in relation to light intensity/conditions, moisture availability and disturbance level making them suitable indicators of anthropogenic disturbance. The presence of invasive/weed species is also good indicator of disturbances levels.

Attempts have been made to use vegetation to assess and monitor ecological conditions in wetlands in UT (Handa et al. 2012). This study found that a majority of the wetlands in the UT were dominated by weedy species implying they contained low nutrients and resilience. The study proposed five indicator plant groups including the *Cynodon dactylon*, *Schkuhria pinnata, Oxygonum sinuatum,* and *Tagetes minuta* wetland indicator community that was characterized by soils with high phosphorous and potassium contents but with low soil moisture content and were areas intensively cultivated or cropped with food crops. The *Leersia hexandra* sub-community was closely associated with high soil moisture content as well as total carbon and nitrate levels.

The *Malva parviflora* indicator sub-community was typical of mid-montane inland valleys of the UT and was strongly associated with pH and electrical conductivity. Other key wetland plants of this group included *Chenopodium album, C. opulifolium, C. murale, Taraxacum officinale, Setaria verticillata, Cyperus rotundus* and *Eleusine indica*. The *Oxalis corniculata* sub-community was significantly associated with high phosphorous levels in soils. Other typical species of the group include *Commelina benghalensis, Centella asiatica, Galinsoga urticifolia, Vernonia poskeana, Kyllinga alata,* and *Stellaria media*. Finally, the *Typha capensis* sub-community was characteristic of high electrical conductivity and permanent inundated wetlands. Other associated species in Typha clade include *Celosia trigyna, Epilobium hirsutum and Paspalum vaginatum*.

5.2 Approach developing provisional BCG for vegetation

Based on our expert knowledge and experience one can assess the environmental conditions of a site by analyzing data distribution and occurrences of vegetation species. For example weedy and invasive species are known to occupy open and degraded areas while areas intact are difficult to invade. Such localities tend to support secondary to primarily vegetation cover that is indicative of a stable and pristine environment. Meanwhile areas under transition are likely to support mixture of vegetation species. We hypothesize BCG can use the relative abundances of various vegetation species to describe environmental conditions of localities (Table 5). Five attributes relevant to developing BCG for vegetation are: (i) Historically documented, sensitive, long-lived, or regionally endemic taxa, (ii) sensitive species, (iii) taxa of immediate tolerance, (iv) tolerance taxa, and (v) ecosystem connectance. For vegetation, there are significant overlaps between species found in various tiers as such to minimize overlaps and confusions Tiers 1 and 2 were merged and described together. Expected responses of various vegetation species to environmental stresses is provided in Appendix 3.

Table 5: BCG for vegetation

Resource Condition Tiers (BCG)	Attributes
1 ***Natural or native condition*** ***and*** 2 ***Minimal changes in structure of the biotic community and minimal changes in ecosystem function***	**I *Historically documented, sensitive, long-lived, or regionally endemic taxa.*** Long-lived native species of plants and their associates that are sensitive to environment changes and can be used to describe pristine environments are Orchidaceae in primary forests of indigenous forest of *Podocarpus* and *Juniperus*. In wetlands, Water Lily, *Cyperus papyrus* and *Typha domingensis* are indicative of native conditions. Understory and herbs associated with pristine forests are *Impatiens hoehnelii* and *Impatiens fischeri*. **II *Sensitive taxa*** Sensitive taxa are expected to occur naturally and in significant populations in the UT Watershed are Orchidaceae in indigenous forests of *Podocarpus, Vitex keniensis and Juniperus.* In wetlands, Water Lily, *C. papyrus* and *T. domingensis are* indicative of native conditions. Bryophytes and Pteridyphytes (ferns) occur along streams, rivers and trees trunks in intact indigenous forests. Fungi (mushrooms) are indicator of pristine environments. Understory and herbs associated with pristine forests are *I. hoehnelii* and *I. fischeri*. **III: *Taxa of intermediate tolerance.*** The following taxa can used to describe Tier 1 in wetlands: *C. papyrus, C. exaltatus* and in terrestrial habitats: *Juniperus, Newtonia buchananii, Ekerbergia capensis, Albizia gummifera*.

	IV *Tolerant taxa:* Epiphytic ferns are tolerant taxa but their presence in substantial population is an indicative of pristine environments/forests. **IX *Ecosystem connectance*:** Distribution and occurrences of sensitive, native/indigenous, and endemics in an area will inform about the ecological conditions of habitats in an area. Some of the species to assess their occurrences and distribution are *C. papyrus, T. domingensi*, Water Lily, *Podocarpus, Juniperus, Vitex keniensis* (Meru oak), *Prunus africana*, Ficus trees, *Syzygium guineense* and *Maesa lanceolata.*
3 ***Evident changes in structure of the biotic community and minimal changes in ecosystem function***	**I *Historically documented, sensitive, long-lived, or regionally endemic taxa.*** Long-lived native species and sensitive to environment changes. The following can be used in assessing terrestrial environments: Orchidaceae, *V. keniensis*, *P. africana*, Ficus trees, *S. guineense* and *M. lanceolata* and in wetlands: Water lily. **II *Sensitive taxa/Taxa of intermediate tolerance.*** No sensitive taxa is proposed to describe these conditions. **III: *Taxa of intermediate tolerance.*** Taxa expected under this category are *Cyperus exaltatus* (Giant sedge) and Water lily. **IV *Tolerant taxa:*** Occurrence and densities of tolerant taxa are expected to be in at natural population. Some of weedy species occur suc as *Biden pilosa* and *Emilia* species. Also sites are likely to support different populations of the following non native or intentionally introduced taxa: -*Lantana camara, Prosopis juliflora* (Mathenge), *Solanium mauritianum, Ipomoea* species, *Parthenium hysterophorus, Nicotiana glauca, Phragmites australis* (Common Reed), *P. maruritanus* (Reed Grass), *Eichornia crassipes* (Water hyacinth), *Pistia stratiotes* (River Cabbage), *Azolla pinnata* (Mosquito Fern). **IX *Ecosystem connectance*:** Distribution and occurrences of sensitive, native/indigenous, and endemics in an area will inform about the ecological conditions of habitats in an area. Examples of species to study occurrences and distribution are *C. papyrus*, Giant sedge, Water Lily, *B. pilosa, Emilia* species, *Podocarpus, Juniperus, V. keniensis, P. africana*, Ficus trees, *S.guineense* and *M. lanceolata*.
4 ***Moderate changes in structure of the biotic community and minimal changes in ecosystem function***	**I: *Historically documented, sensitive, long-lived, or regionally endemic taxa*** Long-lived native species of vegetation sensitive to environment changes. Two species very common along riverine are relevant under this category: *S. guineense* and *M. lanceolata*. **II: *Sensitive taxa/Taxa of intermediate tolerance.*** No Sensitive taxa are known to tolerate these conditions. **III: *Taxa of intermediate tolerance.*** Taxa relevant under this category is Giant sedge. **IV: *Tolerant taxa.*** Occurrence and densities of tolerant taxa are as naturally occur. Some of weedy species relevant under this category are *B. pilosa* and *Emilia* species.

	V: Non native or intentionally introduced species: locations are likely to support different populations of the following non native or intentionally introduced taxa: -*L. camara, P. juliflora, S. mauritianum, Ipomoea* species, *P. hysterophorus, N. glauca, P. australis* (Common Reed), *P. maruritanus* (Reed Grass), *E. crassipes* (Water hyacinth), *P. stratiotes* (River Cabbage), *A. pinnata* (Mosquito Fern). **IX: *Ecosystem connectance*:** Distribution and occurrences of moderate or intermediate native/indigenous, and endemics in an area will inform about the ecological conditions of habitats in an area. Examples of these species are Giant sedge, *B. pilosa, Emilia* species, *S. guineense* and *M. lanceolata*.
5 ***Major changes in structure of community***	**I *Historically documented, sensitive, long-lived, or regionally endemic taxa*** . No vegetation taxa is proposed under this category. **II *Sensitive taxa/Taxa of intermediate tolerance.*** No taxa is proposed under this category. **III: *Taxa of intermediate tolerance.*** Vegetation under this category in wetlands are *C. papyrus* whereas in terrestrial environments are different native and exotic weedy species. **IV *Tolerant taxa:*** Occurrence and densities of Tolerant taxa are as naturally occur. Three taxa are representative of this category: *C. papyrus, B. pilosa* and *Emilia* species. **V: Non native or intentionally introduced species:** locations are likely to support different populations of the following non native or intentionally introduced taxa: -*L. camara, P. juliflora* (Mathenge), *S. mauritianum, Ipomoea* species, *P. hysterophorus, N. glauca, P. australis* (Common Reed), *P. maruritanus* (Reed Grass), *E. crassipes* (Water hyacinth), *P. stratiotes* (River Cabbage), *A. pinnata* (Mosquito Fern). **IX *Ecosystem connectance*:** Distribution and occurrences *C. papyrus, B. pilosa* and *Emilia* species will inform about the ecological conditions of habitats in an area. Enhance distribution will indicate low ecological health/condition.
6 ***Severe changes in structure of the biotic community and major loss of ecosystem functions***	**I: *Historically documented, sensitive, long-lived, or regionally endemic taxa:*** No vegetation are proposed for this category. **II: *Sensitive taxa/Taxa of intermediate tolerance:*** Sensitive and immediate taxa are not expected to be present. **III: *Taxa of intermediate tolerance:*** No taxa under this category **IV: *Tolerant taxa:*** Occurrence and densities of tolerant taxa are as naturally occur. Native weedy species are relevant for this category: *B. pilosa* and *Emilia* species.. **V: Non native or intentionally introduced species:** Site expected to support to support different populations of the following non native or intentionally introduced taxa: -*L. camara, P. juliflora, S. mauritianum, Ipomoea* species, *P.*

	hysterophorus, N. glauca, P. australis, P. maruritanus, E. crassipes, P. stratiotes, A. pinnata. **IX: *Ecosystem connectance*:** Distribution and occurrences native weedy species such as *B. pilosa* and *Emilia* species will inform about the ecological conditions of habitats in an area. Enhanced distribution will indicate low ecological health/condition.

5.3 Limitation and way forward

The provisional vegetation BCG is based on available literature review, expert knowledge and experience on occurrences and distribution of species. Data and information exists for distribution and occurrences for many vegetation species in UT. There is need in the near future to carry more studies to enhance its relevance and usability. Overall use of vegetation to assess landscape or watershed conditions offer a lot of promise as it is easy and robust approach. But distinction needs to be made on which land use types (i.e forests, agricultural landscapes etc) one is focusing on and which macrohabitats (wood lots, riverine forests etc)

CHAPTER SIX

PROVISIONAL BCG FOR FISHES OF THE UPPER TANA

Edward Njagi and Joseph Gathua

6.1 Introduction

Monitoring of surface waters have recently advanced from measurement of physicochemical parameters to the use of biological indicators as early warning signals of ecosystem degradation (Raburu and Masese, 2010). Fish are very good indicators of change as a result of their mobility and sensory perception of many species which allow them to avoid environmental perturbations, and thus they can show a rapid response to environmental change. By studying their dynamics using biological metrics (Cairns 1974, Karr 1981) and examining their ecological preferences and pollution tolerances, the presence, absence and proportionate abundance of fish can be used to indicate the quality of physical, chemical and biological conditions of aquatic environments in which they live (Karr et al. 1986). Fish stocks are termed as resilient if they are able to withstand environmental change without noticeable recruitment fluctuations. Non resilient stocks would then be indicators of environmental change, responding to primary environmental factors such as temperature, salinity, upwelling and pollutants as well as reflecting an environmental coupling to food chain or habitat fluctuations.

One of the tools used for monitoring change using fish has been the use of Index of Biotic Integrity (IBI), which was originally developed for fish assemblages in small streams in Midwestern United States of America (Karr et al. 1986). The IBI uses attributes of the fish assemblage in a stream reach to assess the condition of a stream and its catchment, relative to eco-regional standards. The IBI integrates land-water linkages, physical habitat quality, hydrological regime, energy inputs, biological interactions and water quality (Karr et al. 1986, Steedman 1988). In its original form, the IBI was designed to combine information from individual, population, assemblage and ecosystem levels into a numerical indicator and quality rating for water bodies (Karr et al. 1986). The IBI combines fish assemblage attributes classified into groups of richness and composition, trophic composition, abundance and health or condition (Karr 1981). Each attribute or metric is an expression of a known influence of human activities on different aspects of the fish assemblage which responds in a different manner to aquatic ecosystem stressors (Fausch et al. 1990).

The Biological Condition Gradient (BCG) is a conceptual, scientific framework for interpreting biological response to increasing effects of stressors on aquatic ecosystems (US EPA 2016). It describes how measurable characteristics of aquatic ecosystems change in response to increasing levels of stress, from a natural condition (undisturbed or minimally disturbed by modern human activities) to severely altered conditions (highly disturbed). In the BCG framework, these measurable characteristics are defined as attributes of the biological communities and the physical habitat that reflect the condition of an aquatic ecosystem (US EPA 2016). The BCG uses many of the metrics, or attributes, of the IBI. However it is not reliant on specific monitoring protocols and does not compute a numeric score. The BCG is divided into six levels of biological condition along the stress-response curve, ranging from observable biological conditions found at no or low levels of stress (level 1 or also described as Tier 1) to those found at high levels of stress (level 6 or Tier 6).

In Kenya, a few attempts have been made to develop a Fish Based Index of Biotic Integrity (FIBI) for monitoring riverine ecosystems in the Lake Victoria drainage basin (Raburu & Masese 2010). Some of the metrics considered included an assessment of species richness and composition, indicator species or guilds, reproduction functions, abundance, conditions and trophic functions (Raburu & Masese 2010). Based on these studies, the following can be preliminarly concluded on the response of fishes to environmental stress. Fish species considered to be intolerant to pollution include though not present in the Upper Tana include *Mormyrus kannume, Gnathonemus longibarbis, Barbus neumayeri, Labeobarbus altianalis, Oreochromis variabilis, Schilbe mystus* and *Bagrus docmak* (Raburu & Masese, 2010). Mormyrids are known to be sensitive to degradation, especially sedimentation, because it affects their stream bed habitat (Hugueny et al. 1996, Toham & Teugels 1998). The Genus *Oreochromis* is generally considered to be tolerant to physico-chemical changes (Raburu & Masese 2010). Members of rheophilic species are useful in assessing effects of poor agricultural practices and deforestation, which cause sedimentation and loss of habitat diversity and heterogeneity (Hocutt et al. 1994, Ganasan & Hughes 1998, Toham & Teugels, 1999). Toham & Teugels (1998, 1999) found cyprinids to be useful indicators of ecosystem degradation due to their relatively high species richness and broad geographical distribution over a wide range of conditions in tropical West African streams while Raburu & Masese (2010) noted that Cyprinids were widely distributed from the source of the rivers to the lower reaches but were conspicuously absent in severely degraded areas but dominant in sites with good habitats and water quality in Lake Victoria Basin.

6.2 Approach

The development of the BCG began with the assembly and analysis of biological fish data derived from collections based at the Ichthyology Section of the National Museums of Kenya (NMK) and literature review of fishes found Kenya. An experts' workshop was held during which experts familiar with fish species were tasked to assess and define these fishes preferred ecological condtions. The final phase comprised experts assigning various sites to BCG Tiers using species assemblages.

The conceptual model of the BCG is intended to be universal (US EPA 2016, Davies & Jackson 2006), but descriptions of communities, species, and their responses to the anthropogenic stress gradient are specific to the conditions and communities found in the sample region. Before assigning fish species to BCG Tiers, the expert panel began by describing the biological condition levels that could be discerned within their region. The description of natural conditions requires biological knowledge of the region, a natural classification of the assemblages and historical descriptions of the habitats and assemblages. The panelists examined species composition and abundance data from sites with different levels of cumulative stress, ranging from least stressed to severely stressed. Panel members discussed the species composition and what they expect to see for each level of the BCG and then assign sites or samples to BCG Tiers.

These site assignments were used to describe changes in the aquatic communities for a range of anthropogenic stress, leading to a complete descriptive model of the BCG for the UT region. A preliminary BCG using fishes is summarized below (Table 6). The response of each fish to a gradient of environment stress is provided as Appendix 4.

Table 6: BCG for fishes

Resource Condition Tiers	**Attributes**
1 **Natural or native condition**	**I *Historically documented, sensitive, long-lived with complex life requirements, or regionally endemic taxa.*** Long-lived native fish species with single or multiple habitats required. Fishes under this category are Rainbow trout *Onchorynchus mykiss,* Brown trout *Salmo trutta* and the Mountain Catfish *Amphilius uranoscopus.* The African Mottled Eel *Anguilla bengalensis* fits also qualify under this category because its complex life cycle that include breeding in the sea and living in freshwater. **II *Sensitive taxa.*** Sensitive taxa are expected to be common and abundant. The following taxa are representative of this group*:* Rainbow- and Brown Trout, which are sensitive to both the thermal gradient and pollution. In warm water habitats, the Magadi Tilapia *Alcalicus grahami*, common in saline lakes in Kenya fall into this category. **III *Taxa of intermediate tolerance.*** Some of the species that fall into this category include the Mountain cat fish *Amphilius uranoscopus*, Dembea Stone Lapper *Garra dembeensis*, Sucker Mouth *Chiloglanis brevibarbis*, *Labeo cylindricus* and *Barbus paludinosus*. **IV *Tolerant taxa.*** Occurrence and densities of tolerant taxa are as naturally occur. The following taxa are representative of this category: African Catfish *Clarias gariepinus,* Nile Tilapia *Oreochromis niloticus niloticus,* Athi River Tilapia *Oreochromis spilurus spilurus*, Pangani Barb *Labeobarbus oxyrhynchus,* Red-eye Labeo *Labeo cylindricus*, Straight Bin Barb *Barbus paludinosus* and Common Carp *Cyprinus carpio.* **V *Nonnative or intentionally introduced taxa.*** Nonnative taxa are absent or, if they occur, their presence does not displace native biota or alter natural structure and function. Nile Tilapia, Athi River Tilapia and Common Carp could occur in this area and belongs to this category. The trout species are considered "naturalized" even though not native, hence the reason they have been described under Attribute 1. **IX *Ecosystem connectance***. The connectivity between upper, middle and lower reaches of river is important for fishes that require these habitats for their survival. Allows for access to habitats and maintenance of seasonal cycles are necessary for life history requirements such as colonization sources and refugia

	during extreme events. Fishes known to migrate are Short Fin Eel *Anguila bicolor bicolor*, Long Fin Eel *Anguilla mossambica* and African Mottled Eel.
2 **Minimal changes in structure of the biotic community and minimal changes in ecosystem function**	**I *Historically documented, sensitive, long-lived, regionally endemic taxa.*** Some regionally endemic, long-lived species may be absent due to local extirpation; Fishes that could be found here include Mountain Catfish and the Rainbow Trout though these two species do not co-exist. **II *Sensitive taxa.*** Richness of specialist taxa is high though densities may be low. Here, the Rainbow Trout could be found but with very low abundances. Below this is where there is a distinct line between the Rainbow Trout and the Mountain Catfish. **III *Taxa of intermediate tolerance.*** Fishes found here could include the Victoria Mouth Brooder *Pseudocrenilabrus victoriae*, Million Fish *Poecilia reticulata* and Eastern Mosquito Fish *Gambusia affinis holbrooki* **IV *Tolerant taxa.*** May be slight increases in occurrence of tolerant taxa such Red Eye Labeo, Straight Fin Barb, African Cat Fish *(Clarias gariepinus)*, Nile Tilapia and *Oreochromis spilulus* **V *Nonnative or intentionally introduced taxa.*** . Nile Tilapia, Athi River Tilapia and Common Carp could occur in this area and belongs to this category. **IX *Ecosystem connectance*** Unimpaired access to habitats, and maintenance of seasonal cycles necessary to fulfill life history requirements and to provide colonization sources and refugia for extreme events. Fishes found here include: all freshwater eels of the family Anguillidae.
3 **Evident changes in structure of the biotic community and minimal changes in ecosystem function**	**I *Historically documented, sensitive, long-lived, or regionally endemic taxa.*** **Fishes.** Brown Trout and Rainbow trout may be present if coldwater habitats are present. **II *Sensitive taxa.*** Some replacement of taxa having narrow or specialized environmental requirements. The Mountain Catfish can be used if coldwater habitats under consideration but their population n might be significantly reduced due to the introduction of non-native Brown Trout and the Rainbow trout. **III *Taxa of intermediate tolerance*.** The following fish assemblages expected to show increase populations: Dembea Stone Lapper, Eastern Mosquito Fish and Million Fish. Increase in the number of Pangani Barb and Red Eye Labeo could also be noted. **IV *Tolerant taxa.*** Some of the species present here include the Athi Tilapia, Nile and the African Catfish.

	V ***Nonnative or intentionally introduced taxa:*** Brown and Rainbow Trout replaces the Mountain Catfish in the upper reaches. The Mountain Catfish moves to lower reaches. **IX** ***Ecosystem connectance*****:** Development along rivers, including the Seven Forks Dams expected to impede migration of fishes especially the Short Fin Eel, Long Fin Eel and the African Mottled Eel. However records of these species past the hydro dams into the upper Tana has been reported.
4 **Moderate changes in structure of the biotic community and minimal changes in ecosystem function**	**I** ***Historically documented, sensitive, long-lived, regionally endemic taxa.*** Most of the species found here are introduced, Rainbow and Brown Trout are usually absent. **II.** ***Sensitive taxa.*** The Rainbow and Brown Trout are absent in this area due to increasing temperatures and reduced water quality. An increase in the number of Cyprinids could be noted. **III.** ***Taxa of intermediate tolerance.*** The Mountain Catfish will be found here but in low abundances. Others include the Common Carp, Eastern Mosquito Fish and the Million Fish. **IV.** ***Tolerant taxa:*** Fishes unders this category include reproducing populations of the Nile Tilapia that may have escaped from fish farms in the area, *Oreochromis spirulus* and the African Catfish. Members of the family Cyprinidae also occur in these conditions. The fishes are able to withstand harsh environmental conditions. **V.** ***Nonnative or intentionally introduced taxa.*** Eastern Mosquito Fish, Million fish, Common Carp and the Nile Tilapia can be used to describe this ecological conditions. **X.** ***Ecosystem connectance***. Some of the fishes that can be used to describe these conditions are Short Fin Eel, Long Fin Eel and the African Mottled Eel.
5 **Major changes in structure of the biotic community and moderate changes in**	**I:** ***Historically documented, sensitive, long-lived, or regionally endemic taxa.*** Under this category fish taxa are largely absent. **II:** ***Sensitive taxa*** – not expected to occur in this tier. **III** ***Taxa of intermediate tolerance:*** Fish species capable of withstanding these condtions if present in very low numbers, indicating impaired recruitment and/or reproduction. They are Million Fish and Eastern Mosquito Fish.

ecosystem function	**IV:** ***Tolerant taxa.*** Frequent occurrence of tolerant collector and gatherers. Native fish species are essentially absent with the exception of tolerant taxa like the Africa Catfish. The Nile Tilapia and the Athi Tilapia may be present but in very low abundances. **V:** ***Nonnative or intentionally introduced taxa:*** The introduced Nile Tilapia and the Common Carp could be present but in very low abundance. **IX** ***Ecosystem connectance:*** Lateral connectance to floodplain areas is eliminated except at peak flows due to altered channel morphology caused by human intervention (bank riprapping, dykes) and altered flow regime. Barriers (dams, culverts) contribute to impairment of fish passage such that the eels are not able to migrate to the ocean for breeding where their young ones are unable to move upstream.
6 **Severe changes in structure of the biotic community and major loss of ecosystem function**	**I:** ***Historically documented, sensitive, long-lived, regionally endemic taxa.*** All fish species identified in Attribute I for Tiers 1 and 2 absent. **II:** ***Sensitive taxa/Taxa of intermediate tolerance.*** Here fish species are usually **a**bsent, though an occasional transient individual, usually in poor condition, may be collected. **IV:** ***Tolerant taxa:*** Low dissolved oxygen conditions, high turbidity or presence of toxic substances preclude survival of most fish taxa except those with special adaptations to deficient oxygen conditions The African Catfish may be present in very low abundance. **V:** ***Nonnative or intentionally introduced taxa:*** Native species are essentially absent. **IX:** ***Ecosystem connectance:*** The eels are not able to migrate for breeding in the sea due to alteration of stream morphology and catchment as well as wide spread land use disturbances.

6.3 Limitations

The fish species BCG was developed based on minimal literature view and expert knowledge on occurrences and distribution of fishes in Kenya. Data on fish occurrences in the UT was found to be scanty and insufficient to give a complete list of fish species found in the area. Just like other taxonomic groups, there is a need to carry more studies on distribution and abundances of fishes in the UT. Meanwhile fish offer are also potential and suitable candidates for monitoring ecological conditions in the UT.

CHAPTER SEVEN

PROVISIONAL BCG FOR AMPHIBIAN OF UPPER TANA

Patrick K. Malonza and George G. Ndiritu

7.1 Introduction

Amphibians are one of the animal groups that play an important role in the food webs of most biological communities (Scott & Seigel 1992). Their biphasic life, short generation turnover, permeable skin and ease to sample, make them easy to study (Heyer et al.1994, Green 1997). Naturally amphibians are one of the animal groups sensitive to environmental change, condition and quality (Pineda & Halffter 2004, Wake & Vredenburg 2008). For example, amphibians are more easily affected by changes in the local environment because of their limited movement capacity and strong philopatry, high fidelity, high susceptibility to desiccation, narrow moisture and temperature tolerances plus specific breeding habitat requirements. Their highly permeable thin skin makes them vulnerable to chemical and physical changes in both terrestrial and aquatic habitats (Bell & Donnelly 2006). Indeed the biphasic mode of life (moisture dependent in wetland or aquatic systems) and their permeable skin easily detects changes in chemicals and other substances in the environment. The survival of the amphibian fauna all over the world is under threat as a result of a variety of causes, apparently related to global climate change, which is attributed to habitat alteration through habitat loss, degradation, modification and disturbance. Other threats to amphibians are pollution and diseases such as fungal infection.

Habitat loss and/or modification does not affect all species equally (Pineda & Halffter 2004), with the most affected being the rare species, food specialists, species with low dispersal abilities, habitat specialist (burrowing, stream and forest floor dwellers) and species with low population densities or high population variability. The least affected are habitat generalists that are known to be widespread, abundant and can tolerate wide range of habitat changes or disturbance level; for such species what is important for their survival is open water for breeding. Meanwhile there are always varying levels of tolerance and an elastic limit depending on the kind of stressor e.g. level and kind of pollution to any species. Response of amphibians to varying levels of disturbances or stressors in their habitat/environment can be assessed and monitored using a number of amphibian abundances and distribution attributes of:

i. Presence/absence of species.
ii. Population: abundance of species.
iii. Individuals' adult size of particular species e.g. body length and weight (mass)
iv. Age structure and evidence of life cycle completion (ratios of juveniles: sub-adults: adults).
v. Reproductive capacity and fecundity: evidence of breeding or not.
vi. Species physiology: health status (presence of diseases e.g. fungal infection and others, endo and ecto-parasites), body deformities.

Noticeably the above mentioned amphibian attributes can be organized and used to assess and monitor environmental conditions in wetlands and their associated watersheds. Use of Amphibians to monitor environmental conditions in the UT Watershed is justified by the fact 54 anura species are known to occur in central and western highlands of Kenya (Lötters et al. 2006).

This is significant number of anurans particularly when considered that there are approximately 100 Amphibian species known from Kenya (Channing and Howell 2006, NMK Herpetology collection). In addition a fairly large number of studies have been carried in Kenya on occurrences and distribution of amphibians (Burgess et al. 1998, Lötters et al. 2005, Schick et al. 2005, Bekele et al. 2006, Malonza et al. 2006, 2010, 2011; Pau et al. 2006, Wasonga et al. 2007, Malonza & Veith 2011, Malonza 2012, 2015; Ong'oa et al. 2013, Bwong et al. 2014, 2017) with some being carried out within the Upper Tana River Watersheds (Lötters et al. 2006, Malonza 2015).

7.2 Approach to development of provisional BCG for Amphibians

According to literature there about 21 species of frogs have been reported in the upper Tana River Watershed, thirteen of these species are widespread while the rest are more Kenya highlands endemic (Appendix 5). Based on available information it possible to assess how each of species population is likely to respond to increasing environmental stress.

Based on expert knowledge one can be able to assess the environmental conditions of a site by analyzing data on amphibian species distribution and occurrences. In addition almost all of these species can be surveyed and identified by vocalization because frog calls are species specific. Amphibians (e.g. frogs and toads) are mostly active at night when they congregate in breeding sites. In these breeding sites (e.g. river beds, streams, ponds, pools and swamps), calls from male frogs are followed to their source as these are species specific. Using acoustic calls one can estimate the number of different species in any given wetland.

Specifically information on amphibian species presence/absence, population sizes, body size, age structure, fecundity and health status can be used to select the most relevant attributes to describe the six resources condition tiers of the BCG (Table 7). For amphibian, the following six attributes are proposed to describe the six BCG tiers:

- **Attribute I: Historically documented, sensitive, long-lived, or regionally endemic taxa**. These are amphibian species that are long-lived and native species in an area.
- **Attribute II: Sensitive taxa**. Sensitive taxa are common and abundant hence approximately expected to occur naturally. Apart from presence/absence data; abundance ratios of particular age groups and activity to determine the relative abundance of sensitive as well as intermediate and tolerant species.
- **Attribute III: Taxa of intermediate tolerance: ?**
- **Attribute IV: Tolerant taxa** Occurrence and densities of Tolerant taxa that naturally occur.
- **Attribute VI: Organism condition:** Species living in polluted habitats are highly susceptible to skin diseases, redundant growth, deformities and physiological stress.
- **Attribute VIII: Spatial and temporal extent of detrimental effects:** interprets smaller scale condition as well as evaluate long term impacts, recovery or

restoration potential of habitats. Species can re-colonize habitats once the condition improves following rehabilitation or restoration.

- **Attribute IX: Ecosystem connectance**: species living in pristine environment and migration corridors whereas those in degraded areas are likely to be isolated and therefore unable to access breeding and feeding grounds.

Table 7: BCG for Amphibians

Resource Condition Tiers (BCG)	Attributes
1 ***<u>Natural or native condition</u>***	**I: *Historically documented, sensitive, long-lived, or regionally endemic taxa.*** Regionally endemic amphibians and sensitive to environmental changes. Amphibian species present include Irangi or Mt. Kenya Puddle frog and Tigoni or Silver-bladder Reed Frog. **II: *Sensitive taxa.*** Sensitive taxa are expected to occur naturally in the Upper Tana Watershed are Silver-bladder Reed Frog, Montane Reed Frog *Hyperolius montanus,* Kirinyaga Toad *Sclerophrys kerinyagae,* Mahnerts Ridged Frog, Kenya Puddle Frog **III: *Taxa of intermediate tolerance.*** Taxa expected to occur are: Nutt's River Frog, Montane Reed Frog *Hyperolius montanus*. **IV: *Tolerant taxa.*** Occurrence and densities of Tolerant taxa are as naturally occur. Two taxa are representative of this category: Peter's Reed Frog (*Hyperolius glandicolor*), Mascarene Ridged Frog, Savanna ridged frog and, Guttural Toad. **VI: *Organism condition*:** Marsabit Clawed Frog, Ridged frogs e.g. Mascarene Ridged Frog, Guttural Toad can be used under this category. Observable condition e.g deformities, fungal infection, skin colour, inactive tadpoles, physiological stress. **VIII: *Spatial and temporal extent of detrimental effects***: Survey of different sites or at different watershed scales at different times and analyse the presence/absence, species/age group abundance data. **IX: *Ecosystem connectance*:** Distribution and occurrences of specialists and endemics in an area will inform about the ecological conditions of habitats in an area. Limited distribution will indicate low ecological health/condition. Certain habitat types like extensive farmlands/settlements are barriers to the dispersal of some species. These can be identified after mapping species presence and absence and examining distribution gaps.
2 ***<u>Minimal changes in structure of the biotic</u>***	**I: *Historically documented, sensitive, long-lived, or regionally endemic taxa.*** Regionally endemic species of amphibian and sensitive to environment changes. Amphibian species present include Kirinyaga Toad and Tigoni/Silver-bladder Reed Frog. **II: *Sensitive taxa.*** Sensitive taxa are expected to occur naturally in the Upper

community and minimal changes in ecosystem function	Tana Watershed is Tigoni or Silver-bladder Reed Frog, Kenya Montane Reed Frog, Kirinyaga Toad. **III:** ***Taxa of intermediate tolerance.*** Nutt's River Frog and Crowned Bull Frog **IV:** ***Tolerant taxa***. Occurrence and densities of Tolerant taxa are as naturally occur. Three taxa are representative of this category: Guttural toad and Peter's Reed Frog, Mascarene ridged frog. **VI:** ***Organism condition.*** Check deformities, fungal infection, skin colour, inactive tadpoles, physiological stress. Marsabit Clawed Frog, Mascarene Ridged Frog, Guttural Toad. **VIII:** ***Spatial and temporal extent of detrimental effects.*** Species surveys in different sites to assess species presence or absence at different scales e.g. site, micro-watershed, sub-watershed, watershed scales **IX** ***Ecosystem connectance.*** Distribution and occurrences of specialists, endemics and generalists in an area will inform about the ecological conditions of habitats in an area. Limited distribution will indicate low ecological health/condition and /or presence of species barriers.
3 ***Evident changes in structure of the biotic community and minimal changes in ecosystem function***	**I:** ***Historically documented, sensitive, long-lived, or regionally endemic taxa.*** Long-lived native species of amphibian and sensitive to environment changes. No amphibian species qualify under this category are expected to occur. **II:** ***Sensitive taxa.*** Sensitive taxa is expected to occur are Kinangop Puddle Frog, Kirinyaga toad. **III:** ***Taxa of intermediate tolerance.*** Taxa expected under this category is Nutt's River Frog **IV** ***Tolerant taxa.*** Occurrence and densities of Tolerant taxa that naturally occur. Three taxa are representative of this category: Peter's Reed Frog, Mascarene Ridged Frog and Guttural toad. **VI:** ***Organism condition***. Health, deformities, diseases: Marsabit Clawed Frog, Guttural Toad, Mascarene Ridged frog can be used.**VIII:** ***Spatial and temporal extent of detrimental effects***. Surveys conducted more widely in different sites to indicate presence or absence of certain species at different scales – site, microwatershed, subwatershed, watershed scales. **IX** ***Ecosystem connectance.*** Distribution and occurrences of Peter's Reed frog, Mascarene Ridged Frog, Guttural Toad and Nutt's River Frog in an area will inform about the ecological conditions of habitats in an area. Limited distribution will indicate low ecological health/condition and presence of barriers
4 ***Moderate changes in structure of the biotic***	**I:** ***Historically documented, sensitive, long-lived, or regionally endemic taxa.*** Long-lived native species of amphibian and sensitive to environment changes. No amphibian species qualify under this category are expected to occur.

community and minimal changes in ecosystem function	**II:** ***Sensitive taxa.*** No Sensitive taxa are expected to occur at this tier. **III:** ***Taxa of intermediate tolerance.*** Taxa expected under this category are Nutt's River Frog **IV:** ***Tolerant taxa.*** Occurrence and densities of Tolerant taxa (opportunistic) are as naturally occur. Three taxa are representative of this category: Peter's reed Frog, Guttural Toad, Nutt's River Frog, Mascarene Ridged Frog and Savanna Ridged Frog **VI:** ***Organism condition.*** Condition of Peter's Reed Frog, Guttural Toad, Marsabit Clawed Frog can be used. **VIII:** ***Spatial and temporal extent of detrimental effects.*** Sample at different sites and at different watershed scales. **IX:** ***Ecosystem connectance*****:** Distribution and occurrences of Nutt's River Frog, Mascarene Ridged Frog and Savanna Ridged Frog in an area will inform about the ecological conditions of habitats in an area. Limited distribution will indicate low ecological health/condition.
5 ***Major changes in structure of amphibian community***	**I:** ***Historically documented, sensitive, long-lived, or regionally endemic taxa.*** Long-lived native species of amphibian and sensitive to environment changes. No amphibian species qualify under this category are expected to occur. **II:** ***Sensitive taxa.*** No species expected to occur at this tier. **III:** ***Taxa of intermediate tolerance.*** No species expected to occur at this tier. **IV** ***Tolerant taxa.*** Occurrence and densities of Tolerant taxa are as naturally occur. Species abundance reduced to low levels. Four taxa are representative of this category: Savanna Ridged Frog, Guttural Toad, Peters Reed Frog and Mascarene Ridged Frog **VI:** ***Organism condition.*** Condition of Marsabit Clawed Frog, Guttural Toad and Mascarene Ridged Frog can be used under this category. **VIII:** ***Spatial and temporal extent of detrimental effects***. Surveys can be conducted more widely than a site and indicate species presence or absence at different scales – site, micro-watershed, sub-watershed, watershed scales **IX** ***Ecosystem connectance.*** Distribution and occurrences tolerant species in an area will inform about the ecological conditions of habitats in an area. Limited distribution will indicate low ecological health/condition.
6 ***Severe changes in structure of the biotic community and major loss of ecosystem***	**I:** ***Historically documented, sensitive, long-lived, or regionally endemic taxa.*** Long-lived native species of amphibian and sensitive to environment changes. No amphibian species qualify under this category are expected to occur. **II:** ***Sensitive taxa.*** No species expected to occur at this tier. **III:** ***Taxa of intermediate tolerance.*** No taxa expected to occur at this tier. **IV** ***Tolerant taxa.*** Occurrence and densities of tolerant taxa are as naturally occur. Abundances highly reduced with some being absent. Three taxa are

functio**ns**	representative of this category: Guttural Toad, Mascarene Ridged Frog, Savanna Ridged Frog **VI:** ***Organism condition.*** Condition of Guttural Toad and Mascarene Ridged Frog can be used under this category. **VIII.** ***Spatial and temporal extent of detrimental effects.*** surveys are conducted more widely than a site and indicate presence or absence at different scales – site, micro-watershed, sub-watershed, watershed scales. **IX.** ***Ecosystem connectance.*** Distribution and occurrences of Savanna Ridged Frog, Guttural Toad and Mascarene Ridged Frog in an area will inform about the ecological conditions of habitats in an area. Limited distribution will indicate low ecological health/condition.

7.3 Conclusions, limitations and the way forward

The provisional amphibian BCG presented above is based on knowledge on occurrences and distribution of species. It must be noted that no focused quantitative studies have been carried to determine environmental conditions where these species are found. What is known is that amphibians are very unique species as their life histories constitute both terrestrial and aquatic/wetland phases that make them suitable candidates to assess and monitor environmental conditions in both wetlands and terrestrial habitats. The amphibians are very common, abundant and widespread in the UT Watershed are therefore highly recommended in monitoring environmental conditions in the area. However, the limitation is that certain amphibian species can naturally decline or decrease in abundance or disappear and later re-appear when the conditions are good or improve for their survival. This aestivation may compromise and complicate environmental condition assessments. In addition on seasonal basis timing is very crucial as some species breed within a very short period and disappear or aestivate and sampling after this may make one to conclude that they are absent or very low in abundance. It is recommended that sampling be spread from start of wet season, its peak and towards the end.

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APPENDICES

Appendix 1: List of macroinvertebrates found in UT and their expected responses to increasing stress levels

Expected population response of species under increasing stress level (Biological Condition Gradient Tiers) (H=High; S=Stable; L=Low; A=absent)

				BCG Tiers					
Order/Class	**Family**	**Species**	**Attributes**	**1**	**2**	**3**	**4**	**5**	**6**
Coleoptera	Psephenidae	*Psephenus sp*	II	H	S	L	L	A	A
Diptera	Tipulidae	*Tipulus sp*	II	H	S	L	L	A	A
Ephemeroptera	Heptageniidae	*Afronurus harrisonii*	II	H	S	L	L	A	A
Ephemeroptera	Prosopistomatidae	*Prossopistoma sp*	II	H	S	L	L	A	A
Plecoptera	Perlidae	*Neoperla kunensis*	II	H	S	L	L	A	A
Bivalvia	Sphaeridae	*Pisidium sp*	III	L	S	S	L	L	L
Coleoptera	Gyrinidae	*Aulonogyrus hypoxanthus*	III	L	S	S	L	L	L
Coleoptera	Dytiscidae	*Copelatus sp*	III	L	S	S	L	L	L
Coleoptera	Helodidae	*Cyphon sp*	III	L	S	L	L	L	L
Coleoptera	Elmidae	*Elmis sp*	III	L	S	S	L	L	L
Decapoda	Potamonautidae	*Potamonautes alluaudi*	III	L	S	L	L	L	L
Decapoda	Potamonautidae	*Potamonautes odhneri*	III	L	S	L	L	L	L
Diptera	Simulidae	*Simulium sp*	III	L	S	L	L	L	L
Ephemeroptera	Baetidae	*Baetis harisonii*	III	L	S	L	L	L	L
Ephemeroptera	Caenidae	*Caenis sp*	III	L	S	L	L	L	L
Hemiptera	Geriidae	*Eurymetra natalensis*	III	L	S	L	L	L	L
Odonata	Libellulidae	*Pantala flavescens*	III	L	S	L	L	L	L
Odonata	Chlorocyphidae	*Platycypha auripes*	III	L	S	L	L	L	L
Odonata	Chlorocyphidae	*Platycypha caligata*	III	L	S	L	L	L	L
Odonata	Coenagrionidae	*Pseudogarion kerstenii*	III	L	S	L	L	L	L

Odonata	Libellulidae	*Trithermis sp*	III	L	S	L	L	L	L
Trichoptera	Hydropsychidae	*Aethaloptera maxima*	III	L	S	L	L	L	L
Trichoptera	Ecnomidae	*Parecomina sp*	III	L	S	L	L	L	L
Trichoptera	Hydropsychdae	*Promacrostemum sp*	III	L	S	L	L	L	L
Coleoptera	Ptilidae	*Dactylosterma sp.*	IV	L	L	S	S	L	L
Coleoptera	Hydrophilidae	*Hydrophilus sp*	IV	L	L	S	S	L	L
Coleoptera	Staphylinidae	*Phildonthes pseudobyssinus*	IV	L	L	S	S	L	L
Diptera	Chironomidae	*Chironomus sp*	IV	L	L	S	S	L	L
Diptera	Culicidae	*Culex sp*	IV	L	L	S	S	L	L
Diptera	Tabanidae	*Haematopota sp*	IV	L	L	S	S	L	L
Gastropoda	Planorbidae	*Burnupia sp*	IV	L	L	S	S	L	L
Gastropoda	Thiaridae	*Melanoides tuberculata*	IV	L	L	S	S	L	L
Hemiptera	Corixidae	*Anisops amaryllis*	IV	L	L	S	S	L	L
Hemiptera	Notonectidae	*Enithares chinai*	IV	L	L	S	S	L	L
Hemiptera	Naucoridae	*laccocoris limigenus*	IV	L	L	S	S	L	L
Hemiptera	Mesoveliidae	*Mesovelia sp*	IV	L	L	S	S	L	L
Hemiptera	Corixidae	*Micronecta sp*	IV	L	L	S	S	L	L
Hemiptera	Saldidae	*Saldula sp*	IV	L	L	S	S	L	L
Isopoda	Isopdae	*Isopoda sp*	IV	L	L	S	S	L	L
Odonata	Coenagrionidae	*Africallagma glaucum*	IV	L	L	S	S	L	L
Odonata	Lestidae	*Lestes sp*	IV	L	L	S	S	L	L
Diptera	Muscidae		IV	A	A	L	S	H	H
Diptera	Psychodidae		IV	A	A	L	S	H	H
Diptera	Syrphidae	*Erastalis sp.*	IV	A	A	L	S	H	H
Oligochaetea	Oligochaetae	*Tubifex sp*	IV	L	L	S	S	H	H
Decapoda	Cambaridae	*Procambarus clarkii*	V	L	L	S	S	L	L

Appendix 2: List of birds recorded in the Upper Tana and their expected population response under increasing stress levels.

Expected population response of species under increasing stress level (Biological Condition Gradient Tiers) (H=High; S=Stable; L=Low; A=Absent) (Forest Dependency codes– FF = Forest specialists, F = Forest Generalists, f = Forest Visitors, non-f = non-forest species)

					Study site											**Expected population response**					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
Phasianidae: quails, francolins, spurfowl and allies																					
Crested Guineafowl	*Guttera pucherani*	F	LC										x			S	H	S	D	D	D
Scaly Francolin	*Pternistis squamatus*	F	LC										x			S	H	S	D	D	D
Jackson's Francolin	*Francolinus jacksoni*	F	LC				x		x							S	H	S	D	D	D
Egyptian Goose	*Alopochen aegyptiaca*	Non f	LC							x											
Anatidae: ducks and geese																					
African Black Duck	*Anas sparsa*	Non f	LC					x	x					x							
Yellow-billed Duck	*Anas undulata*	Non f	LC							x											
Yellow-billed Stork	*Mycteria ibis*	Non f	LC							x											
Ciconiidae: storks																					
Abdim's Stork	*Ciconia abdimii*	Non f	LC											x							
Sacred Ibis	*Threskiornis aethiopicus*	Non f	LC							x											
Olive Ibis	*Bostrychia olivacea*	Non f	LC				x														

					Study site											Expected population response					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
Threskiornithidae: ibises and spoonbills																					
Hadada Ibis	*Bostrychia hagedash*	Non f	LC		x			x		x	x			x	x						
African Spoonbill	*Platalea alba*	Non f	LC							x											
Ardeidae: herons, egrets and bitterns																					
Cattle Egret	*Bubulcus ibis*	Non f	LC							x											
Black-headed Heron	*Ardea melanocephala*	Non f	LC			x				x											
Purple Heron	*Ardea purpurea*	Non f	LC							x											
Yellow-billed Egret	*Ardea intermedia*	Non f	LC							x											
Scopidae: Hamerkop																					
Hamerkop	*Scopus umbretta*	Non f	LC			x						x									
Phalacrocoracidae: cormorants																					
Great Cormorant	*Phalacrocorax carbo*	Non f	LC					x				x									
Accipitridae: diurnal birds of prey other than falcons																					
African Black-shouldered Kite	*Elanus caeruleus*	Non f	LC											x							
African Harrier Hawk	*Polyboroides typus*	f	LC		x	x										L	L	S	H	H	H
Great Sparrowhawk	*Accipiter melanoleucus*	F	LC						x					x		S	H	S	L	L	L
Mountain Buzzard	*Buteo oreophilus*	FF	NT	AfrH			x							x		S	S	L	L	A	A
Augur Buzzard	*Buteo augur*	Non f	LC		x	x	x			x	x	x	x								
Wahlberg's Honeybird	*Prodotiscus regulus*	Non f	LC											x							
Martial Eagle	*Polemaetus bellicosus*	FF	VU											x		S	S	L	L	A	A

					Study site											Expected population response					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
Long-crested Eagle	*Lophaetus occipitalis*	Non f	LC			x	x														
Crowned Eagle	*Stephanoaetus coronatus*	FF	NT											x		S	S	L	L	A	A
Gruidae: cranes																					
Grey Crowned Crane	*Balearica regulorum*	Non f	EN							x											
Columbidae: Doves and Pigeons																					
African Olive Pigeon	*Columba arquatrix*	F	LC				x		x		x			x	x	S	H	S	L	L	L
Lusky Turtle dove	*Streptopelia lugens*	f	LC											x	x	L	L	S	H	H	H
ReL-eyed dove	*Streptopelia semitorquata*	f	LC		x	x				x	x		x		x	L	L	S	H	H	H
Ring-neckeL dove	*Streptopelia capicola*	f	LC											x		L	L	S	H	H	H
EmeralL-spotted Wood-dove	*Turtur chalcospilos*	f	LC											x	x	L	L	S	H	H	H
Tambourine dove	*Turtur tympanistria*	F	LC						x			x		x		S	H	S	L	L	L
African Green Pigeon	*Treron calvus*	F	LC											x		S	H	S	L	L	L
Psittacidae: Lovebirds and Parrots																					
Red-fronted Parrot	*Poicephalus gulielmi*	FF	LC												x	S	S	L	L	A	A
Musophagidae: turacos																					
Hartlaub's Turaco	*Tauraco hartlaubi*	FF	LC	AfrH			x		x					x	x	S	S	L	L	A	A
Cuculidae: cuckoos and coucals																					
Klaas's Cuckoo	*Chrysococcyx klaas*	f	LC											x		L	L	S	H	H	H
African Emerald Cuckoo	*Chrysococcyx cupreus*	F	LC											x		S	H	S	L	L	L
White-browed Coucal	*Centropus*	Non f	LC			x															

					Study site											**Expected population response**					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
	superciliosus																				
Caprimulgidae: nightjars																					
Montane Nightjar	*Caprimulgus poliocephalus*	F	LC											x		S	H	S	L	L	L
Speckled Mousebird	*Colius striatus*	Non f	LC		x	x		x		x		x	x	x	x						
Narina Trogon	*Apaloderma narina*	F	LC						x							S	H	S	L	L	L
Trogonidae: trogons																					
Bar-tailed Trogon	*Apaloderma vittatum*	FF	LC	AfrH					x							S	S	L	L	A	A
AlceLinidae: kingfishers																					
Malachite Kingfisher	*Corythornis cristatus*	Non f	LC			x				x											
Giant Kingfisher	*Megaceryle maxima*	Non f	LC									x									
Meropidae: bee-eaters																					
Cinnamon-chested Bee-eater	*Merops oreobates*	F	LC	AfrH										x		S	H	S	L	L	L
Bucerotidae: hornbills																					
Crowned Hornbill	*Tockus alboterminatus*	f	LC				x		x					x		L	L	S	H	H	H
Silvery-cheeked Hornbill	*Bycanistes brevis*	F	LC				x							x	x	S	H	S	L	L	L
Captonidae: barbets and tinkerbirds																					
White-eared Barbet	*Stactolaema leucotis*	F	LC												x	S	H	S	L	L	L
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	F	LC			x			x	x			x	x	x	S	H	S	L	L	L
Indicatoridae: honeyguides																					
Lesser Honeyguide	*Indicator minor*	f	LC					x								L	L	S	H	H	H

					Study site											Expected population response					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
Picidae: wrynecks and woodpeckers																					
Fine-banded Woodpecker	*Campethera tullbergi*	FF	LC	AfrH											x	S	S	L	L	A	A
Cardinal Woodpecker	*Dendropicos fuscescens*	f	LC											x		L	L	S	H	H	H
Platysteiridae: batises, wattle-eyes and relatives																					
Chin-spot Batis	*Batis molitor*	Non f	LC		x	x		x		x	x	x		x	x						
Malaconotidae: helmetshrikes, bushshrikes, tchagras and puffbacks																					
Brown-crowned Tchagra	*Tchagra australis*	Non f	LC			x								x							
Black-backed Puffback	*Dryoscopus cubla*	F	LC			x	x					x			x	S	H	S	L	L	L
Tropical Boubou	*Laniarius aethiopicus major*	f	LC			x		x		x	x	x				L	L	S	H	H	H
Campephagidae: cuckooshrikes																					
Black Cuckooshrike	*Campephaga flava*	f	LC												x	L	L	S	H	H	H
Laniidae: shrikes																					
Common Fiscal	*Lanius collaris*	Non f	LC		x			x		x		x		x							
Oriolidae: orioles																					
Montane Oriole	*Oriolus percivali*	FF	LC	AfrH	x									x	x	S	S	L	L	A	A
ABlack-headed Oriole	*Oriolus larvatus*	f	LC												x	L	L	S	H	H	H
Monarchidae: monarch flycatchers																					
African Paradise Flycatcher	*Terpsiphone viridis*	f	LC		x	x		x	x	x	x	x	x	x		L	L	S	H	H	H
White-tailed Crested Flycatcher	*Elminia albonotata*	F	LC	AfrH					x							S	H	S	L	L	L
Corvidae: crows and allies																					

					Study site											Expected population response					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
Pied Crow	*Corvus albus*	Non f	LC		x	x		x				x		x							
Paridae: tits																					
White-bellied Tit	*Parus albiventris*	f	LC						x					x		L	L	S	H	H	H
HirunLinidae: saw-wings, swallows and martins																					
White-headed Saw-wing	*Psalidoprocne albiceps*	f	LC												x	L	L	S	H	H	H
Black Saw-wing	*Psalidoprocne pristoptera*	f	LC		x	x		x	x	x	x	x	x		x	L	L	S	H	H	H
Plain Martin	*Riparia paludicola*	Non f	LC				x	x													
Wire-tailed Swallow	*Hirundo smithii*	Non f	LC			x															
Rock Martin	*Ptyonoprogne fuligula*	Non f	LC		x																
Cisticollidae: cisticolas and allies																					
ReL-faceL Cisticola	*Cisticola erythrops*	Non f	LC			x		x		x		x									
Singing Cisticola	*Cisticola cantans*	Non f	LC			x		x				x									
Hunter's Cisticola	*Cisticola hunteri*	F	LC	AfrH	x				x	x	x		x	x	x	S	H	S	L	L	L
Tawny-flanked Prinia	*Prinia subflava*	f	LC									x				L	L	S	H	H	H
Black-collared Apalis	*Apalis pulchra*	F	LC	AfrH					x					x		S	H	S	L	L	L
Yellow-breasted Apalis	*Apalis flavida*	f	LC											x		L	L	S	H	H	H
Black-throated Apalis	*Apalis jacksoni*	FF	LC				x		x							S	S	L	L	A	A
Chestnut-throated Apalis	*Apalis porphyrolaema*	F	LC	AfrH				x	x					x	x	S	H	S	L	L	L
Grey Apalis	*Apalis cinerea*	FF	LC						x						x	S	S	L	L	A	A
Grey-capped Warbler	*Eminia lepida*	f	LC		x	x					x	x	x			L	L	S	H	H	H

					Study site											Expected population response					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
Grey-backed Camaroptera	*Camaroptera brachyura*	f	LC						x		x	x	x		x	L	L	S	H	H	H
Pycnonotidae: bulbuls																					
Common Bulbul	*Pycnonotus barbatus*	f	LC		x			x				x			x	L	L	S	H	H	H
Mountain Greenbul	*Adropadus nigriceps*	FF	LC	AfrH			x		x						x	S	S	L	L	A	A
Yellow-whiskered Greenbul	*Eurillas latirostris*	F	LC										x			S	H	S	L	L	L
Cabanis's Greenbul	*Phyllastrephus cabanisi*	FF	LC						x							S	S	L	L	A	A
Slyviidae: old world warblers																					
Evergreen Forest Warbler	*Bradypterus lopezi*	FF	LC						x							S	S	L	L	A	A
Cinnamon Bracken Warbler	*Bradypterus cinnamomeus*	F	LC	AfrH					x		x	x				S	H	S	L	L	L
Brown Woodland Warbler	*Phylloscopus umbrovirens*	F	LC	AfrH			x		x							S	H	S	L	L	L
Timaliidae: illadopses, babblers and chatterers																					
African Hill Babbler	*Pseudoalcippe abyssinica*	FF	LC	AfrH			x		x						x	S	S	L	L	A	A
Hinde's Babbler	*Turdoides hindei*	Non f	VU	So-Ma		x						x									
Northern Pied Babbler	*Turdoides hypoleuca*	Non f	LC	So-Ma	x	x				x											
Zosteropidae: white-eyes																					
Montane White-eye	*Zosterops poliogastrus*	F	LC	AfrH					x	x		x			x	S	H	S	L	L	L
Sturnidae: starlings and oxpeckers																					
Greater Blue-eared Starling	*Lamprotornis chalybaeus*	Non f	LC												x						

					Study site											Expected population response					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
Kenrick's Starling	*Poeoptera kenricki*	FF	LC	AfrH											x	S	S	L	L	A	A
TurdiLae: thrushes																					
Olive Thrush	*Turdus olivaceous*	F	LC						x						x	S	H	S	L	L	L
Brown-chesteL Alethe	*Alethe poliocephala*	FF	LC						x						x	S	S	L	L	A	A
Muscicapidae:chats, wheatears and old world flycatchers																					
White-starred Robin	*Pogonocichla stellata*	F	LC	AfrH			x		x							S	H	S	L	L	L
Cape Robin Chat	*Cossypha caffra*	F	LC		x		x	x		x	x	x				S	H	S	L	L	L
Rüppell's Robin Chat	*Cossypha semirufa*	F	LC	AfrH		x			x	x	x			x		S	H	S	L	L	L
Common Stone Chat	*Saxicola torquatus*	Non f	LC		x						x		x								
White-eyed Slaty Flycatcher	*Meleanornis fischeri*	F	LC	AfrH										x	x	S	H	S	L	L	L
Southern Black Flycatcher	*Melaenornis pammelaina*	Non f	LC									x									
African Lusky Flycatcher	*Muscicapa adusta*	F	LC					x	x		x	x	x	x	x	S	H	S	L	L	L
Nectariniidae: sunbirds																					
Collared Sunbird	*Hedydipna collaris*	F	LC		x				x		x			x		S	H	S	L	L	L
Green-headed Sunbird	*Cyanomitra verticalis*	F	LC						x			x			x	S	H	S	L	L	L
Olive Sunbird	*Cyanomitra olivacea*	FF	LC												x	S	S	L	L	A	A
Tacazze Sunbird	*Nectarinia tacazze*	f	LC	AfrH				x								L	L	S	H	H	H
Bronze Sunbird	*Nectarinia kilimensis*	f	LC	AfrH	x	x		x		x	x					L	L	S	H	H	H
GolLen-wingeL Sunbird	*Drepanorhynchus reichenowi*	f	LC	AfrH									x	x	x	L	L	S	H	H	H

					Study site											Expected population response					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
Northern double-collareL Sunbird	*Cinnyris reichenowi*	F	LC	AfrH	x			x	x		x	x		x	x	S	H	S	L	L	L
Eastern double-collareL Sunbird	*Cinnyris mediocris*	F	LC	AfrH			x									S	H	S	L	L	L
Variable Sunbird	*Cinnyris venustus*	f	LC					x			x	x		x	x	L	L	S	H	H	H
Passeridae: sparrow weavers, Old World sparrows and petronias																					
Kenya Rufous Sparrow	*Passer cordofanicus rufocinctus*	Non f	LC		x						x										
Grey-headed Sparrow	*Passer griseus*	Non f	LC												x						
Grey-headed Sparrow	*Passer griseus*	Non f	LC			x															
Ploceidae:weavers, bishops and widowbirds																					
Grosbeak Weaver	*Amblyospiza albifrons*	f	LC			x		x								L	L	S	H	H	H
Baglafecht Weaver	*Ploceus baglafecht*	f	LC	AfrH	x	x		x		x	x	x	x	x	x	L	L	S	H	H	H
Spectacled Weaver	*Ploceus ocularis*	f	LC			x		x		x		x		x		L	L	S	H	H	H
Holub's Weaver	*Ploceus xanthops*	Non f	LC		x			x		x		x									
Village Weaver	*Ploceus cucullatus*	Non f	LC			x				x		x									
Brown-capped Weaver	*Ploceus insignis*	FF	LC	AfrH					x	x					x	S	S	L	L	A	A
Yellow Bishop	*Euplectes capensis*	Non f	LC								x										
Estrildidae: waxbills																					
Yellow-bellied Waxbill	*Coccopygia quartinia*	f	LC		x			x						x		L	L	S	H	H	H
Abyssinian Crimsonwing	*Cryptospiza salvaLorii*	F	LC	AfrH											x	S	H	S	L	L	L
Common Waxbill	*Estrilda astrild*	Non f	LC		x	x		x	x	x		x		x							
Purple Grenadier	*Granatina*	Non f	LC	So-										x							

					Study site											Expected population response					
Common Name	***Scientific Name***	**Forest Dependency**	**status**	**biome**	**Bogiti**	**Githambara**	**Gitwiga**	**Gura River**	**Kimakia**	**Mitai**	**Ndiara**	**Tambaya**	**Thegu Bridge**	**Thegu Ele Fence**	**Thegu Trout Farm**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5**	**Tier 6**
	ianthinogaster			Ma																	
ReL-billed Firefinch	*Lagonosticta senegala*	Non f	LC					x						x							
Bronze Mannikin	*Spermestes cucullata*	Non f	LC		x	x		x		x	x	x									
Viduidae: Parasitic Weaver, indigobirds and whydahs																					
Pin-tailed Whydah	*ViLua macroura*	Non f	LC							x											
Motacillidae: wagtails, longclaws and pipits																					
Cape Wagtail	*Motacilla capensis*	Non f	LC			x		x		x		x	x								
Mountain Wagtail	*Motacilla clara*	F	LC					x	x			x		x	x	S	H	S	L	L	L
African Pied Wagtail	*Motacilla aguimp*	Non f	LC			x					x	x		x	x						
Fringillidae: canaries, citrils, seedeaters and relatives																					
Yellow-crowned Canary	*Serinus flavivertex*	f	LC											x	x	L	L	S	H	H	H
African Citril	*Crithagra citrinelloiLes*	f	LC	AfrH	x	x		x		x		x		x							
Reichenow's Seedeater	*Crithagra reichenowi*	Non f	LC											x							
Streaky Seedeater	*Crithagra striolata*	f	LC	AfrH	x	x	x	x		x	x	x		x		L	L	S	H	H	H
Thick-billeL Seedeater	*Crithagra burtoni*	FF	LC	AfrH			x						x			S	S	L	L	A	A
Oriole Finch	*Linurgus olivaceus*	F	LC										x			S	H	S	L	L	L
Emberizidae: Old World buntings																					
GolLen-breasted Bunting	*Emberiza flaviventris*	Non f	LC											x							

Appendix 3: List of plants in the Upper Tana and their expected population response to increasing increasing stress levels

Expected population response of species under increasing stress level (Biological Condition Gradient Tiers) (H=High; S=Stable; L=Low; A=Absent)

	Family/Species/group	**Common name**	**Comments**	**BCG Tiers**					
				1	**2**	**3**	**4**	**5**	**6**
1	Orchidaceae		Some Endemic to UT, riverine/swamp specific	H	S	L	L	A	A
2	Bryophytes			H	S	L	A	A	A
3	Water lily		Wetland plants	H	H	S	L		
4	*Asplenium hypomelas*		Epiphytic (Ferns) are sensitive	H	S	L	L	A	A
5	*Asplenium theciferum*		Epiphytic fern	H	S	L	L	A	A
6	*Lepisorus excavatus*		Epiphytic fern	H	S	L	L	A	A
7	Cyathea manniana	Tree fern	Riverine	H	S	L	A	A	A
8	*Maratti afraxinea*		Riverine	H	L	L	A	A	
9	Lichens		Remain dormant until conditions are favorable		H	S	L	A	A
10	Mushroom		Forest mushrooms	H	H	S	L		
11	*Azolla pinnata*	Mosquito fern				S	S	H	H
12	*Lantana camara*					S	H	H	H
13	*Prosopis juliflora*					S	H	H	H
14	*Solanium mauritianum*					S	H	H	H
15	*Ipomoea species*					S	H	H	H
16	*Parthenium hysterophorus*					S	H	H	H
17	*Nicotianaglauca*					S	H	H	H
18	*Phragmites australis*	Common reed				S	H	H	H
19	*P. maruritanus*	Reed grass				S	H	H	H
20	*Eichornia crassipes*	Water hyacinth				S	H	H	H
21	*Pistia stratiotes*	River cabbage				S	H	H	H
22	*Typha domingensis*		detect hydrological changes	S	S	S	L	L	
23	*Cyperus papyrus*		Wetland plants	S	S	S	L	L	
24	*Cyperus exaltatus*	Giant sedge			S	S	L		

	Family/Species/group	**Common name**	**Comments**	**BCG Tiers**					
25	*Carex monostachyus*			H	S	L		A	
26	*Alchemilla johnstonii*			H	S	L	A		
27	*Juniperus*				S	S	S	L	
28	*Markhamia ma lascariensis*					S	S		
29	*Podocarpus*				S	S	L	L	A
30	*Vitex keniensis*	Meru oak	Endemic in Mt. Kenya		S	S	L	L	
31	*Prunus africana*		CITES listed, IUCN Endangered	H	S	S	L	L	
32	*Albizia gummifera*		Riverine species	H	H	L	L	A	A
33	*Neoboutania macrocalyx*		Riversine species	H	S	L		A	A
34	*Newtonia buchananii*	Newtonia	Riverine species	H	L	L		A	
35	*Ekerbergia capensis*		Riverine species	H	L			A	A
36	*Ficus sp.*	Fig trees	Cultural significance in Mt. Kenya region			S	L	L	
37	*Impatiens hoehnelii*		Endemic-Mt Kenya	H	S	S	L	A	
38	*Impatiens fischeri*		Endemic-Mt Kenya		S	S	L	A	
39	*Streptocarpus spp.*		Water and shade dependent	H	S	S	A	A	
40.	*Syzygium guineense*		Typically riverine species			S	L	L	
41	*Maesa lanceolata*		Typically riverine species			S	L	L	
42	*Bidens pilosa*		Good indicators of disturbances, land degradation			S	S	H	H
43	Emilia species						S	H	H

Appendix 4: List of fish in the Upper Tana and their expected response to increasing levels of stress

Expected population response of species under increasing stress level (Biological Condition Gradient Tiers) (H=High; S=Stable; L=Low; A=Absent)

			BCG Tiers					
Common name	**Scientific name**	**Conservation Status**	**1**	**2**	**3**	**4**	**5**	**6**
Mountain Catfish	*Amphilius uranoscopus*	LC	L	H	S	L	A	A
Straight Fin Barb	*Enteromius paludinosus*	LC	L	H	H	S	L	A
Kersten's Barb	*Enteromius kerstenii*	LC	L	H	H	S	A	A
Neumayers Barb	*Enteromius neumayeri*	LC	L	H	H	S	A	A
African Mottled Eel	*Anguilla bengalensis labiata*	CE	L	S	H	S	A	A
Short Fin Eel	*Anguilla bicolor bicolor*	NE	L	S	H	S	A	A
Pangani Barb	*Labeobarbus oxyrhynchus*	LC	L	H	H	S	A	A
Red Eye Labeo	*Labeo cylindricus*	LC	L	H	H	S	A	A
Dembea Stone Lapper	*Garra dembeensis*	LC	L	H	H	L	A	A
Sucker Mouth	*Chiloglanis brevibarbis*	NE	L	H	H	L	A	A
Nile Tilapia	*Oreochromis niloticus niloticus*	NE	L	H	H	S	L	A
Athi river Tilapia	*Oreochromis spilurus spilurus*	NE	L	H	H	S	L	L
African Catfish	*Clarias gariepinus*	LC	A	H	H	H	L	L
Common Carp	*Cyprinus carpio*	V	L	H	H	H	L	L
Rainbow Trout	*Onchorhynchus mykiss*	NE	H	S	L	A	A	A
Brown Trout	*Salmo trutta*	LC	H	L	A	A	A	A
Million Fish	*Poecilia reticulate*	LC	L	H	H	S	L	A
Eastern Mosquito Fish	*Gambusia affinis holbrooki*	LC	A	H	H	S	L	A
	Tilapia zilli	V	L	H	H	S	L	A

Appendix 5: List of amphibians and their expected population response under increasing stress levels

Expected population response of species under increasing stress level (Biological Condition Gradient Tiers) (H=High; S=Stable; L=Low; A=Absent)

Common Name	**Scientific Name**	**Distribution**	**Relevant attributes**	**BCG Tiers**					
				1	2	3	4	5	6
Marsabit clawed Frog	*Xenopus borealis*	Widespread	6	L	S	H	S	L	A
Guttural Toad	*Sclerophrys gutturalis*	Widespread	4, 6, 8	L	S	H	S	L	A
Kirinyaga Toad	*Sclerophrys kerinyagae*	Endemic	2	H	S	L	L	A	A
Marbled snout-burrower	*Hemisus marmoratus*	Widespread							
Peter's reed Frog	*Hyperolius glandicolor*	Widespread	4, 8	S	H	S			
Senegal bubbling Kassina	*Kassina senegalensis*	Widespread							
Savanna ridged Frog	*Ptychadena anchietae*	Widespread	3, 4				H	S	L
Mascarene ridged Frog	*Ptychadena mascareniensis*	Widespread	4, 6, 8	L	S	H	H	S	L
Natal puddle Frog	*Phrynobatrachus natalensis*	Widespread							
Nutt's River Frog	*Amietia nutti*	Widespread	3, 9	S	H	S	L	A	A
Mountain River Frog	*Amietia wittei*	Alpine zone	2	H	S	L			

Common Name	**Scientific Name**	**Distribution**	**Relevant attributes**	**BCG Tiers**					
Crowned Bullfrog	*Hoplobatrachus occipitalis*	Restricted range			S	H	S	L	
Lönnberg's dwarf Toad	*Mertensophryne lonnbergi*	Endemic							
Silver-bladder reed Frog	*Hyperolius cystocandicans*	Endemic and endangered		S	S	L			
Kenya montane reed Frog	*Hyperolius montanus*	Endemic and endangered	2	H	S	L	A	A	A
Mahnert's ridged Frog	*Ptychadena mahnerti*	Endemic and endangered	2	H	S	L	A	A	A
Mt. Kenya/Irangi puddle Frog	*Phrynobatrachus irangi*	Endemic and endangered	1	S	A	A	A	A	A
Kenya puddle Frog	*Phrynobatrachus keniensis*	Endemic	1	H	S	L			
Kinangop puddle Frog	*Phrynobatrachus kinangopensis*	Endemic		H	S	L			
Kinangop Caco/dainty Frog	*Cacosternum kinangopensis*	Endemic							
Peter's Reed Frog	*Hyperolius glandicolor*						H	S	L
Tigoni Puddle Frog	*Hyperolius cystocandicans*		1	H	S	L			