IUCN WATER AND NATURE INITIATIVE

PANGANI BASIN WATER BOARD[1]

PANGANI RIVER BASIN FLOW ASSESSMENT

The Vegetation of the Pangani River Basin and its Association with Flow Regimes

P.K.T. Munishi and A. Chitiki

December 2007

[1] As of 2010, Pangani Basin Water Office is known as Pangani Basin Water Board

Published by: Pangani Basin Water Board (PBWB)
International Union for Conservation of Nature (IUCN)

Citation: PBWB/IUCN. (2007). *Pangani River Basin Flow Assessment: The Vegetation of the Pangani River Basin and its Association with Flow Regimes.* Nairobi, KE: IUCN ESARO and Moshi, TZ: PBWB. 80 pp.

Available from: International Union for Conservation of Nature (IUCN) Eastern and Southern Africa Regional Office (ESARO) Publications Service Unit, P. O. Box 68200 - 00200, Nairobi, Kenya; Telephone +254 20 2493561/65; Fax +254 20 2493570; E-mail: earo@iucn.org

THE VEGETATION OF THE PANGANI RIVER BASIN AND ITS ASSOCIATION WITH FLOW REGIMES

BY

PROF. P. K. T. MUNISHI & MR. A.CHITIKI

DEPARTMENT OF FOREST BIOLOGY
SOKOINE UNIVERSITY OF AGRICULTURE
PO BOX 3010 MOROGORO, TANZANIA

FOR

IUCN EASTERN AFRICAN REGIONAL OFFICE, DAR ES SALAAM, TANZANIA

DECEMBER 2007

FINAL REPORT

EXECUTIVE SUMMARY

The Pangani River Basin Flow Assessment (PRBFA) is one of the primary activities that will provide technical information to support water allocation. Its objective is to synthesize present knowledge of the river systems and its users and, in line with the new Tanzanian water policy, to create management tools that will help promote an integrated approach to future water-development and water-allocation decisions. Creation of the tools depends on a substantial investment in new understanding of the links between river flow, the quality of goods and services provided by the river, and the lives and livelihoods of the river users. The process of synthesizing present knowledge on the Pangani ecosystem has begun.

This synthesis has led to identification of a series of specialist studies that are needed to further enhance understanding of the river system and the people of the basin, one of which a focus on exploring how plant species' abundance and distribution may change as a result of alteration of freshwater flow patterns.

The objectives of this vegetation study were therefore to:

- Describe the relationships between the timing and magnitude of freshwater flows in the Pangani system and the biology and life-history characteristics of its key plant species;
- Use these relationships to infer what the historic abundance levels and distribution patterns were for these species in the Pangani catchment (where such information is lacking);
- Predict how abundance and distribution patterns may change in the future under altered flow patterns.

The study used existing vegetation data of the Pangani River Basin (IUCN 2006, Kamugisha *et al.*, 2007) to first describing the longitudinal distribution of the riverine species within the vegetation communities, categorizing them into terrestrial and aquatic, then describing the longitudinal and lateral distribution of the species within vegetation communities in five longitudinal zones of the basin i.e. mountain stream, upper foothill, lower foothill, lower mature river/rejuvenated bedrock cascade and the estuary. Later the drivers of change in this system were identified as well as the ecologically and socio-economically important plant species. Conceptual Models were then developed that show how different species in the different zones of the Pangani River basin will respond to different flow regimes in different seasons *i.e.* median flow during the dry and short rain seasons, 7-day minimum flow during the dry season and the short rain seasons and duration of flow, median flow and small flood peaks during the long rains.

Longitudinally, the terrestrial riverine vegetation communities of the Pangani river system consist of a wide range of tree, shrub, herb, climbers/liana species as well as ferns, and reeds. Herb species make the biggest proportion (25%) followed by trees and shrubs (21%), lianas (19%), grasses (12%), ferns and reeds (1%). There are about 32 tree species and 36 herb species that occur in the Pangani River system. Furthermore the number of shrub, lianas/climbers and grass/fern/reed species was 32, 29 and18 respectively.

Species of the aquatic vegetation were considered as those described as water loving and real aquatic plants. These include a variety of tree, shrub, liana, sedge and grass species (Table 2, Figure 2). In this category there is one fern species, four grass species, two liana species, three shrub species, four tree species, four grass species, six herb species and seven sedge species. Sedges form the highest proportion (30%), followed by herbs (26%) trees, grasses (15%), shrubs (13%), lianas (9%) and ferns (4%)

Generally there are 11 species that can be described as water loving, 16 species as real aquatics and one species as a salt lover. The water loving species occur in areas that are saturated or have high moisture content throughout the year and can be categorized as emergents in aquatic systems. On the other hand the aquatic plants occur in areas that have high soil moisture or under saturated conditions throughout the year and can be more or less submerged all the time

The component species of the Pangani River system are distributed differently along the upstream - downstream zones. The Pangani river system has been classified into five zones, namely mountain stream, upper foothill, lower foothill, rejuvenating bedrock cascade, mature lowland river and the estuary (IUCN 2006). Each of these zones represents specific characteristics of the system and has different vegetation species and community composition and distribution

The estuary's principle vegetation types are sedges, palms and Mangroves. Sedges and lilies are dominant in the upper reaches, while the middle and lower reaches are dominated by palms and mangroves respectively. There is a strong zonation in these communities up the length of the estuary, presumably a function of the salinity distribution in the system

Of these zones, the lower foothill zone was the most species rich in terms of total numbers and aquatic plant species, while the upper foothill was the most species rich in terms of terrestrial plant species.

The different zones of the basin show changes from natural vegetation cover to modified vegetation especially along the riparian zones. Most of these changes seem to be human induced resulting from degradation of natural vegetation giving the exotics a more competitive ability. Exotic species therefore exclude natural vegetation due to vigorous growth at a rate higher than the indigenous vegetation. Some areas were observed to be critically modified as a result of encroachment by exotic species resulting from removal of natural regeneration and bank erosion.

The ecologically important plant species that were identified in the basin included 33 indicator species, 18 keystone species and 11 ecosystem engineers. Socio-economically important plant species include 33 species used as a source of food, 30 species used for medicinal purposes and 15 species used for construction material.

Different flow regimes were considered in the Pangani River basin and they differ with seasons. The flow regimes considered included median flow during the dry and short rain seasons which give the typical flows (cumecs) during the dry season and short rain season, the 7-day minimum flow (cumecs)during the dry season and the short rain seasons which gives a sense of typical low flows during low flow periods, the duration of flow (days) indicating the duration of flows higher than the mean flow during the long rain season, the median flow (cumecs) during the long rains represent the flows higher than the mean flow during the long rains giving a sense of typical high flows, and small flood peaks during the long rains which show the relative stage height of the largest flood peak during the long rains giving a sense of the typical magnitude of high flows.

The response curves developed for representative species could in general terms be grouped according to species growth forms and their lateral distribution on the river cross-section giving three growth forms (trees, shrubs and herbs) and three laterals/cross-sectional zones (aquatic, wet bank and dry bank). Each of the three growth forms and their representative species for each zone seem to respond differently depending on their position on the river cross-section. The curves were then used as input into the preparation of the Pangani Flow Assessment Tool

Aquatic species seem to be more negatively affected by decrease in the 7-day minimum flow and frequency of small flood peaks. On the other hand wet and dry bank species with deep roots tend to be more affected by increasing frequency of flood peaks and duration of flow. Increase in the frequency of flood peaks tend to wash away regenerants and seeds of wet and dry bank species thus suppressing their establishment. Aquatic plants would dry out with decreasing 7-day minimum flow especially during the dry season.

Most of the species of the aquatic system are likely to be impacted more by decreases in the 7-day minimum flow and to some extent the median discharge especially in the dry season. Both species may be affected by duration of flood either negatively or positively. The wet bank species will experience higher impact from fluctuations in the frequency of small flood peak. Frequent flood peaks can suppress regeneration of most wet bank species due to frequent wash out of seedlings and seeds. Deep rooted dry and wet bank species can withstand reduced median flow and sometimes reduced 7-day minimum flows during the dry season. Frequency of flood peaks and prolonged flooding during the rain season (flooding duration) will likely suppress wet and bank species which are not adapted to flooded conditions through possible suffocation. The dynamics of flow regimes will therefore influence survival of plants differently depending on the characteristics of plant species. Further studies should focus on determining the environmental correlates of different plant species distribution to be able to filter out the impacts of different water regimes from other environmental factors. Clear determination of the plant representative species in the four lateral sections of the river i.e. water column, wet bank and dry bank is necessary for more clear understanding of the different responses by different species

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Background to the study

The Pangani Basin Water Office (PWBO) and the World Conservation Union (IUCN) are implementing the Pangani River Basin Management Project, which is supported by the IUCN Water & Nature Initiative, UNDP/GEF and the European Union. The project has several components that will provide technical information and establish participatory processes to support water allocation in the basin.

The Pangani River Basin Flow Assessment (PRBFA) is one of the primary activities that will provide technical information to support water allocation. Its objective is to synthesize present knowledge of the river systems and its users and, in line with the new Tanzanian water policy, to create management tools that will help promote an integrated approach to future water-development and water-allocation decisions. Creation of the tools depends on a substantial investment in new understanding of the links between river flow, the quality of goods and services provided by the river, and the lives and livelihoods of the river users. The process of synthesizing present knowledge on the Pangani ecosystem has begun.

This synthesis has led to identification of a series of specialist studies that are needed to further enhance understanding of the river system and the people of the basin, one of which a focus on exploring how plant species' abundance and distribution may change as a result of alteration of freshwater flow patterns.

1.2 Objectives of the Study

The objectives of this vegetation study were to:

- describe the relationships between the timing and magnitude of freshwater flows in the Pangani system and the biology and life-history characteristics of its key plant species;
- use these relationships to infer what the historic abundance levels and distribution patterns were for these species in the Pangani catchment (where such information is lacking);
- predict how abundance and distribution patterns may change in the future under altered flow patterns.

2.0 SUMMARY DESCRIPTION OF THE PANGANI CATCHMENT

2.1 Geology, geomorphology and drainage

The Pangani River drains the southern side of Africa's greatest mountain (Mt Kilimanjaro) as well as its neighbor (Mt Meru) and a large part of the Pare and Usambara Mountains of the famous Eastern Arc chain in Tanzania. The Pangani River Basin covers about 42,000 km^2 and is shared by Kenya and Tanzania. While the principal sub-catchments of the Pangani are mountainous areas of high precipitation, the main river channel runs through the dry Maasai Steppe of northern Tanzania where rainfall rarely exceeds 500 mm per annum (Figure 1)

Geomorphologically, the Basin constitutes of two units, namely, the highlands and the lowlands also called the "Maasai steppe". The highlands, which comprise steeply sloping mountain terrain rising from 1,000 m to over 2,000 m above sea level are characterized by abundant rainfall (1,200-2,000 mm), high biodiversity, intensive cultivation, urbanization and densely populated rural areas. The highlands hold more than 80% of the basin's inhabitants (IUCN, 2003) and annual population growth rates reach 4%. The lowlands, which comprise of low sloping terrain generally below 1,000 m descending to the coastal plain, receive relatively low rainfall (<500 mm per year), and are characterized by low species biodiversity, scattered croplands, arid rangelands and smaller settlement areas. The population growth rates on the lowlands are close to 2% on average. The coastal plain, with its eastern African coastal and mangrove forests are characterized by high rainfall and species diversity.

2.2 Climate

The climate in the catchment varies considerably, and the Pangani River Basin comprises several sub-catchments of widely different characteristics. The upper parts in the slopes of Mt. Kilimanjaro and Mt. Meru receive 1200-2000 mm rainfall per year, and the rest of the catchment area receives only about 500 mm per year. There are two distinct rainy seasons: a short one from mid October to December and a long one from mid March to June.

2.3 Hydrology

The administrative area of Pangani Basin is situated in the north-east of the country and its rivers drain into the Indian Ocean. The basin consists of four rivers; Umba, Sigi, Msangazi and Pangani River. Of the whole basin the Pangani River, dominates the basin. The catchment covers three regions; Kilimanjaro, Arusha and Tanga. A small part of the catchment is located in Kenya. In Pangani Basin the main abstractions are from surface water (about 95 percent), but the remaining water is taken from ground water sources. There is a significant amount of groundwater potential compared to the other basins in the country. Irrigation is the main ground water user, and accounts for 80 percent of the total abstractions. Boreholes yielding more than 100 cubic metres per hour have been drilled in Kahe plains while boreholes yielding between 10 to 50 $m^3 h^{-1}$ are in Sanya plains and Karoo rocks of Tanga. Groundwater recharge is mainly from rainfall and rivers. The hydrology of the Pangani is characterized by fairly continuous flows though skewed towards low flows given the fact that the short rains have drastically decreased all over the basin over time. The river has several areas of groundwater recharge along its course which may influence flow in the river especially in the lowlands. On the other hand the river also gains from spring discharges such as the Rundugai and Miwaleni springs which makes it a gaining river at some points..

The mean annual flow of the Pangani has decreased over the last four decades but averaged 37 $m^3 s^{-1}$ (IUCN, 2003) although this has been drastically reduced in recent years. The main north-western tributary of the Pangani (the Kikuletwa River) brings slightly sodic waters from the volcanic slopes of Mt Meru and Mt Kilimanjaro while the other northern tributary, the Ruvu River, drains a complex area in Kenya and Tanzania that surrounds Lake Jipe on the international border.

2.4 Vegetation and land cover

The Pangani River basin consists of a variety of vegetation types along its different parts as it flows from the high altitudes on Mts. Kilimanjaro and Meru to the coastal plain. The basin is composed of a relatively intact high forest ecosystem (evergreen forest) on the upper catchment passing through grassland vegetation and cultivated land with different agricultural crops in the middle to lower zone to coastal vegetation as it approaches the ocean. Over the last three decades the Pangani River catchment has undergone major changes in land use/cover, population, agriculture, and socio-economic aspects (Missana, *et al.,* 2003). Much of the original forested zone has been cut and converted to farmlands. The catchment has seen, since the 1960s, changes from traditional farming and pastoralism to irrigation and plantation agriculture mixed with pastoralism (Shishira, 2002), which eventually led to reduced land cover in the catchment (Yanda & Shishira. 1999). At their core, these changes relate to an increasing population against a background of high levels of poverty. The threats faced by the catchment's resources are almost all related to over-exploitation.

2.5 Human settlement and land use

The Pangani River basin has experienced substantial population growth in most parts of the catchment, and it would seem rational to link the water problems to population increases, growing water demand and degradation of water source catchments. Nevertheless, the reasons may be manifold and vegetation cover change seems to form part of such an explanation (Brandon & Bottomley, 1998; Chen, 2000; Diouf & Lambin, 1994; Kuntz & Siegert, 1999).

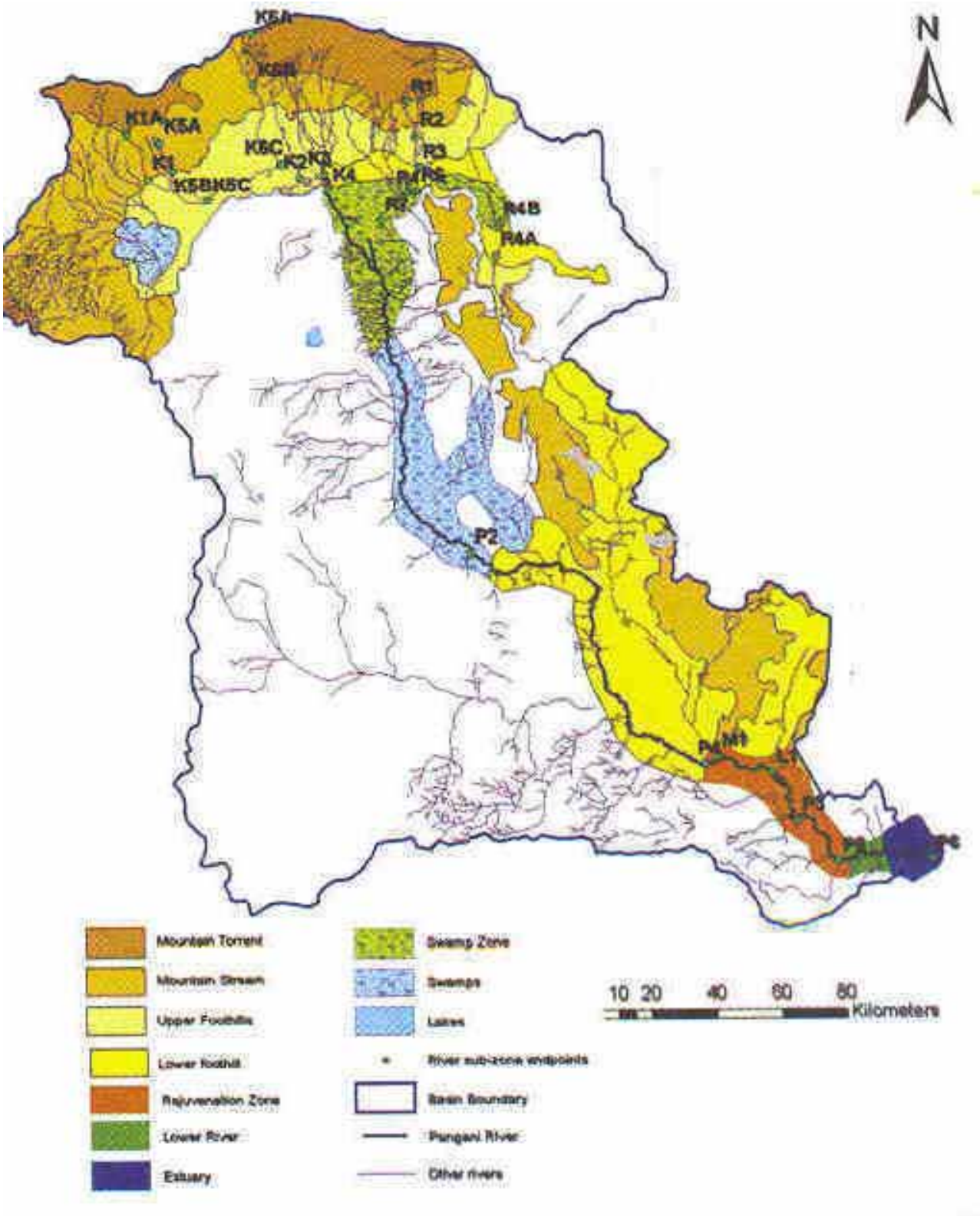

Figure 1 The Pangani River Basin showing the different Ecozones

3.0 VEGETATION OF THE PANGANI RIVER ECOSYSTEM

The descriptions provided here are not of communities, which are ecological assemblages of species that are structured around species interactions and environmental conditions. Rather the descriptions are of species whose distribution co-incide with different geographic and physiographic regions or zones along the Pangani River Basin.

3.1 Riverine Vegetation

The riverine vegetation of the Pangani River ecosystem is composed of terrestrial, aquatic and emergent plant species of different growth forms growing in different lateral zones of the river.

3.1.1 Terrestrial Vegetation

The terrestrial riparian vegetation communities of the Pangani river system consist of a wide range of tree, shrub, herb, climbers/liana species as well as ferns, and reeds (Table 1, Figure 1) (IUCN, 2006a, IUCN 2006b). Herb species make the biggest proportion (25%) followed by trees and shrubs (21%), lianas (19%), grasses (12%), ferns and reeds (1%). There are about 32 tree species that occur in the Pangani River system. The number of herb species is 36. On the other hand the number of shrub, lianas/climbers and grass/fern/reed species is 32, 29 and 18 respectively (Table 1, Figure 2).

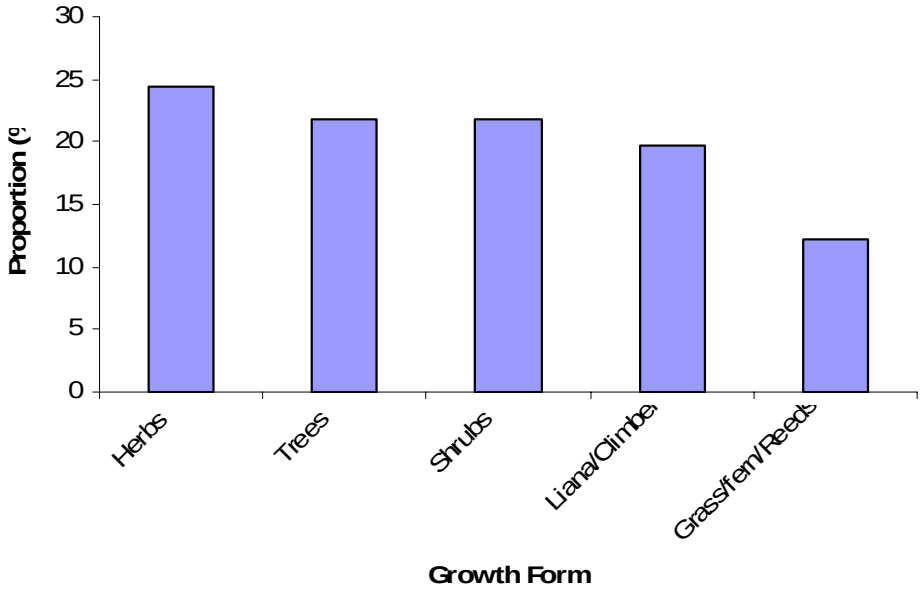

Figure 2 Proportion of species in different growth forms of Terrestrial Riparian Plant Species of the Pangani River system

Table 1 Composition and number of terrestrial riparian plant species occurring in the Pangani river system

Growth Form	SN	Species	Origin	Family
Trees	1	*Acacia albida*	Indigenous	Mimosaceae
	2	*Acacia robusta*	Indigenous	Mimosaceae
	3	*Albizia gummifera*	Indigenous	Mimosaceae
	4	*Albizia petersiana*	Indigenous	Mimosaceae
	5	*Annona senegalensis*	Exotic	Annonaceae
	6	*Bombax rhodognaphalon*	Exotic	Bombacaceae
	7	*Boscia angustifolia*	Indigenous	Capparidaceae
	8	*Aneilema aequinoctiale*	Indigenous	Commelinaceae
	9	*Bridelia cathartica*	Indigenous	Euphorbiaceae
	10	*Bridelia micrantha*	Indigenous	Euphorbiaceae
	11	*Cocos nucifera*	Indigenous	Palmae
	12	*Commiphora pteleifolia*	Indigenous	Burseraceae
	13	*Cordia abyssinica*	Indigenous	Boraginaceae
	14	*Cordia sinensis*	Indigenous	Boraginaceae
	15	*Cussonia arborea*	Indigenous	Araliaceae
	16	*Flacourtia indica*	Indigenous	Flacourtiaceae
	17	*Garcinia livingstonei*	Indigenous	Guttiferae
	18	*Grevilea robusta*	Indigenous	Proteaceae
	19	*Haplocoelium foliolosum*	Indigenous	Sapindaceae
	20	*Kigelia africana*	Indigenous	Bignoniaceae
	21	*Lecaniodiscus fraxinifolius*	Indigenous	Sapindaceae
	22	*Maytenus mossambicensis*	Indigenous	Celastraceae
	23	*Markhamia lutea*	Indigenous	Bignoniaceae
	24	*Parkia filicoidea*	Indigenous	Mimosaceae
	25	*Rauvolfia caffra*	Indigenous	Apocynaceae
	26	*Sapindus saponaria*	Indigenous	Sapindaceae
	27	*Sclerocarya birrea ssp.caffra*	Indigenous	Anacardiaceae
	28	*Spyrostachys africana*	Indigenous	Euphorbiaceae
	29	*Strychnos henningsii*	Indigenous	Loganiaceae
	30	*Trema orientalis*	Indigenous	Typhaceae
	31	*Turraea holstii*	Indigenous	Mimosaceae
	32	*Ziziphus pubescens*	Indigenous	Rhamnaceae
Herbs	1	*Abutilon mauritianum*	Indigenous	Malvaceae
	2	*Acalypha ornate*	Indigenous	Euphorbiaceae
	3	*Acalypha fruticosa*	Indigenous	Euphorbiaceae
	4	*Achyranthes aspera*	Indigenous	Amaranthaceae
	5	*Ageratum conyzoides*	Indigenous	Compositae
	6	*Aloe lateritia*	Indigenous	Aloaceae
	7	*Amaranthus hybridus*	Indigenous	Amaranthaceae
	8	*Bidens pilosa*	Indigenous	Compositae
	9	*Blumea aurita*	Indigenous	Compositae
	10	*Boerhavia repens*	Indigenous	Nyctaginaceae
	11	*Calanchoe prittwitzii*	Indigenous	Caesalpiniaceae
	12	*Cassia mimosoides*	Indigenous	Caesalpiniaceae
	13	*Cenna spectabilis*	Indigenous	Caesalpiniaceae
	14	*Commelina beghalensis*	Indigenous	Commelinaceae
	15	*Corchorus aestuans*	Indigenous	Tiliaceae
	16	*Crotalaria laburnifolia*	Indigenous	Papilionaceae
	17	*Galinsona parviflora*	Indigenous	Compositae

Growth Form	SN	Species	Origin	Family
Herbs	18	*Heliotropium indicum*	Indigenous	Boraginaceae
	19	*Hibiscus micranthus*	Indigenous	Malvaceae
	20	*Justicia betonica*	Indigenous	Acanthaceae
	21	*Justicia glabra*	Indigenous	Acanthaceae
	22	*Krinum kirkii*	Indigenous	Liliaceae
	23	*Melanthera scandens*	Indigenous	Compositae
	24	*Plectranthus kilimandscharica,*	Indigenous	Labiatae
	25	*Prunus africana*	Indigenous	Rosaceae
	26	*Rubus pinnatus*	Indigenous	Rosaceae
	27	*Rubus rosifolius*	Indigenous	Rosaceae
	28	*Saccharum officinarum*	Indigenous	Compositae
	29	*Sida cordifolia*	Indigenous	Malvaceae
	30	*Solanum incanum*	Indigenous	Solanaceae
	31	*Spermacoce laevis*	Indigenous	Ribiaceae
	32	*Spilanthes filicaulis*	Indigenous	compositae
	33	*Talinum portulacifolium*	Indigenous	Portulaceae
	34	*Urtica massaica,*	Indigenous	Urticaceae
	35	*Vangueria madagascariensis*	Indigenous	Rubiaceae
	36	*Withania homnifera*	Indigenous	Solanaceae
Shrubs	1	*Allpohylus africanus*	Indigenous	Sapindaceae
	2	*Antidesma venosum*	Indigenous	Euphorbiacea
	3	*Asystasia gangetica*	Indigenous	Acanthaceae
	4	*Bauhinia tomentosa*	Indigenous	Caesalpiniaceae
	5	*Chaetachme aristata*	Indigenous	Ulmaceae
	6	*Clausena anisata*	Indigenous	Rutaceae
	7	*Clerodendrum rotundifolia*	Indigenous	Tiliaceae
	8	*Combretum pentagonum*	Indigenous	combretaceae
	9	*Flueggea virosa*	Indigenous	Euphorbiaceae
	10	*Grewia conocarpa*	Indigenous	Passiforacea
	11	*Grewia mollis*	Indigenous	Passiforacea
	12	*Harrisonia abyssinica*	Indigenous	Simaroubaceae
	13	*Gardenia transvenulosa*	Indigenous	Rubiaceae
	14	*Leonotis mollissima*	Indigenous	Labiatae
	15	*Macrula Africana*	Indigenous	Moraceae
	16	*Maytenus senegalensis*	Indigenous	Celastraceae
	17	*Ormocarpum kirkii*	Indigenous	Papilionaceae
	18	*Paveta stenocepala*	Indigenous	Rubiaceae
	19	*Phoenix reclinata*	Indigenous	Palmae
	20	*Pluchea dioscoridis*	Indigenous	Bignoniaceae
	21	*Rinorea elliptica*	Indigenous	Vitaceae
	22	*Rothmannia urcelliformis*	Indigenous	Rubiaceae
	23	*Tabernaemontana holstii*	Indigenous	Apocynaceae
	24	*Teclea nobilis*	Indigenous	Rutaceae
	25	*Teclea simplicifolia*	Indigenous	Rutaceae
	26	*Thespesia danis*	Indigenous	Malvaceae
	27	*Toddalia asiatica*	Indigenous	Rutaceae
	28	*Uvaria scheffleri*	Indigenous	Annonaceae
	29	*Uvaria dependens*	Indigenous	Annonaceae
	30	*Vernonia amygdalina*	Indigenous	Bignoniaceae
	31	*Vernonia hildebrandtii*	Indigenous	Bignoniaceae
	32	*Vernonia subuligera*	Indigenous	Bignoniaceae

Growth Form	SN	Species	Origin	Family
Liana/Climber	1	*Acacia brevispica*	Indigenous	Mimosaceae
	2	*Astripomoea malvacea*	Indigenous	Convolvulaceae
	3	*Caesalpinia bonduc*	Indigenous	Caesaipiniaceae
	4	*Cenesio stuhlmannii*	Indigenous	Compositae
	5	*Ceropergia distincta*	Indigenous	Asclepiadaceae
	6	*Cissampelos pereira*	Indigenous	Mimosaceae
	7	*Cissus cordifolia*	Indigenous	Vitaceae
	8	*Cissus intergrifolia*	Indigenous	Vitaceae
	9	*Cissus quandrangularis*	Indigenous	Vitaceae
	10	*Cissus rotundifolia*	Indigenous	Vitaceae
	11	*Flabellaria paniculata*	Indigenous	Malpighiaceae
	12	Flagellaria guineensis	Indigenous	Flagellariaceae
	13	Ipomoea pes- capreae	Indigenous	Convolvulaceae
	14	Glycine wightii	Indigenous	Papilionaceae
	15	Mascarenhasia arborescens	Indigenous	Apocynaceae
	16	Mondia ecornuta	Indigenous	Asclepiadaceae
	17	Mormodica foetida	Indigenous	Cucurditaceae
	18	Mucuna pruriens	Indigenous	Papilionaceae
	19	Passiflora edulis	Indigenous	Passifloraceae
	20	Pergularia daemia	Indigenous	Apocynaceae
	21	Pillaea adiantoides	Indigenous	Adiantaceae
	22	Rhynchosia micrantha	Indigenous	Papilionaceae
	23	Saba comorensis	Indigenous	Apocynaceae
	24	Rubia cordifolia	Indigenous	Ribiaceae
	25	Salacia madagascariensis	Indigenous	Celastraceae
	26	Smilax anceps	Indigenous	Smilacaceae
	27	Solanecio angulatus	Indigenous	Bignoniaceae
	28	Strychnos cocculoides	Indigenous	Loganiaceae
	29	Vigna unguiculata	Indigenous	Papilionaceae
Grass/fern/reeds	1	Brachiaria serrata	Indigenous	Gramineae
	2	Chloris gayana	Indigenous	Gramineae
	3	Cynodon dactylon	Indigenous	Gramineae
	4	Cynodon inlemfuens	Indigenous	Gramineae
	5	Dacyloctenium geminatum	Indigenous	Gramineae
	6	Hyparrhenia filipendula	Indigenous	Compositae
	7	Paspalum scrobiculatum	Indigenous	Compositae
	8	Oplismenus hirtellus	Indigenous	Compositae
	9	Panicum maximum	Indigenous	Compositae
	10	Panicum trichocladum	Indigenous	Compositae
	11	Pennisetum mezianum,	Indigenous	Compositae
	12	Pennisetum purpureum	Indigenous	Compositae
	13	Rottboelia exaltata,	Indigenous	Compositae
	14	Setaria homonyma	Indigenous	Compositae
	15	Sporobolus concimilis	Indigenous	Compositae
	16	Sporobolus pyramidalis	Indigenous	Compositae
	17	Stereospermum cunthianum	Indigenous	Bignoniaceae
	18	Urochloa panicoides	Indigenous	Compositae

3.1.2 Aquatic Plants and Emergents

Species of the aquatic vegetation were considered as those described as water loving and real aquatic plants. Some of these are also wet bank species. These include a variety of tree, shrub, liana, sedge, and grass species (Table 2, Figure 3). In this category there is one fern species, four grass species, two liana species, three shrub species, four tree species, four grass species, six herb species and seven sedge species. Sedges form the highest proportion (30%), followed by herbs (26%) trees (15%), grasses (15%), shrubs (13%), lianas (9%) and ferns (4%)

Generally there are 11 species that can be described as water loving, 16 species as real aquatics and one species as a salt lover. The water loving species occur in areas that are saturated or have high moisture content throughout the year and can be categorized as emergents and/or wet bank species in aquatic systems. On the other hand the aquatic plants occur in areas that have high soil moisture or under saturated conditions throughout the year and can be more or less submerged all the time. The aquatic plants and phytoplankton form the major photosynthesizing plants under water thus the major supply of nutrition to aquatic invertebrates/animals. The water loving plants on the other hand, apart from supplying food for aquatic organisms, may also provide shelter, cover and breeding/spawning sites for aquatic organisms.

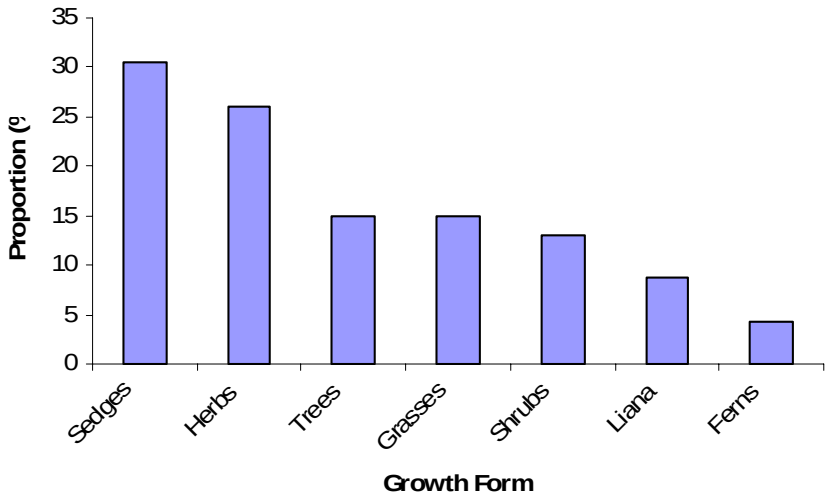

Figure 3 **Proportion of species in different growth forms of aquatic and emergent plant species of the Pangani River system**

Table 2 Aquatic and emergent plant species of the Pangani River system

Growth Form	Species name	Origin	Family
Trees	*Acacia xanthophloea*	Indigenous	Mimosaceae
	Barringtonia racemosa	Indigenous	Leythidaceae
	Celtis africana	Indigenous	Ulmaceae
	Ficus ingens	Indigenous	Moraceae
Shrub	*Sesbania sesbans*	Indigenous	Nymphaceae
	Suaeda monoica	Indigenous	Chenopodiaceae
	Psidium guajava	Indigenous	Myrataceae*
Herbs	*Hibiscus cannabinus*	Indigenous	Malvaceae
	Kanahia laniflora	Indigenous	Asclepiadaceae
	Ludwigia jussiaeoides	Indigenous	Onagraceae
	Mimosa pigra	Indigenous	Gramineae
	Nymphia retusa	Indigenous	Gramineae
	Polygonum senegalense	Indigenous	Polygonaceae
Grass	*Leersia hexandra*	Indigenous	Compositae
	Phragmites mauritianus	Indigenous	Compositae
	Costus afer,	Indigenous	Zingiberaceae
	Drymaria cordata	Indigenous	Caryophylaceae
Lianas	*Mezoneuron angolense*	Indigenous	Caesalpiniaceae
	Mikania cordata	Indigenous	Bignoniaceae
Sedges	*Cyperus alticulatus*	Indigenous	Cyperaceae
	Cyperus distans	Indigenous	Cyperaceae
	Cyperus exaltatus	Indigenous	Cyperaceae
	Cyperus papyrus	Indigenous	Cyperaceae
	Cyperus rotundus	Indigenous	Cyperaceae
	Fimbristylis ferruginea	Indigenous	Cyperaceae
	Kyllinga elata.	Indigenous	Cyperaceae
Ferns	*Acrostichum aureum*	Indigenous	Adiantaceae

3.2 Longitudinal Distribution of Vegetation

The component species of the Pangani River system are distributed differently from the upper to downstream zones. The Pangani river system has been classified into five zones, namely mountain stream, upper foothill, lower foothill, rejuvenating bedrock cascade, mature lowland river and the estuary (IUCN 2006a & b; PBWO/IUCN, 2007). Each of these zones represents specific characteristics of the system and has different plant species and vegetation community composition and distribution (Table 3 – 7, Figures 4 & 5).

3.2.1 The mountain stream zone

This zone may be taken to represent the uppermost zone of the Pangani River system (Figure 1). Most of the species are terrestrial making a total of 77 plant species in this zone. On the other hand the aquatic/emergent plants compose seventeen species (Table 7).

Table 3 Species of the mountain stream zone of the Pangani River system

SN	Species	Family	Growth Form	In Water Column	Wet Bank	Dry Bank
1	*Adenia rumicifolia*	Menispermaceae	Liana			√
2	*Albizia schimperana*	Mimosaceae	Tree			√
3	*Albizia gummifera*	Mimosaceae	Tree			√
4	*Agave sisalana*	Agavaceae	Herb			√
5	*Allophylus africanus*	Sapindaceae	Shrub			√
6	*Acalypha ornata*	Euphorbiaceae	Herb			√
7	*Ageratum conyzoides*	Compositae	Herb			√
8	*Aneilema aequinoctiale*	Commelinaceae	Herb			√
9	*Argemone mexicana*	Papaveraceae	Herb			√
10	*Asystacia gangetica*	Acanthaceae	Herb			√
11	*Aloe latertia*	Acanthaceae	Herb			√
12	*Annona senegalensis*	Annonaceae	Tree			√
13	*Bauhnia tomentosa*	Caesalpiniaceae	Shrub			√
14	*Biden pilosa*	Compositae	Herb		√	√
15	*Blumea aurita*	Compositae	Herb			√
16	*Bridelia micrantha*	Euphorbiaceae	Tree		√	√
17	*Caesalpinia decapitala*	Caesalpiniaceae	Liana			√
18	*Caesalpinia bonduc*	Caesalpiniaceae	Liana			√
19	*Calanchoe prittwitzii*	Caesalpiniaceae	Herb			√
20	*Cenecio stuhlmanii*	Ericaceae	Climber		√	√
21	*Citrus limone*	Rutaceae	Tree			√
22	*Cordia abyssinica*	Boragnaceae	Tree			√
23	*Canna indica*	Cannaceae	Herb			√
24	*Cassia didymobotria*	Caesalpiniaceae	Shrub			√
25	*Cassia floribunda*	Caesalpiniaceae	Shrub			√
26	*Chloris gayana*	Compositae	Grass		√	√
27	*Clerodendrum rotindifolia*	Boragnaceae	Shrub			√
28	*Comelina benguelensis*	Comelinaceae	Herb		√	√
29	*Cordia abyssinica*	Boragnaceae	Tree			√
30	*Costus afer*	Zingiberaceae	Herb		√	√
31	*Croton macrostachyis*	Euphorbiaceae	Tree			√
32	*Cyperus rotundus*	Cyperaceae	Herb/Sedge	√	√	
33	*Dalbergia odovata*	Caesalpiniaceae	Tree			√

34	*Desmodium repandum*	Leguminosae	Herb			√
35	*Digitaria milanjiana*	Poaceae	Herb/Grass			√
36	*Drymaria cordata*	Caryophylaceae	Herb		√	
37	*Englerophytum natalense*	Sapotaceae	Shrub			√
38	*Ficus capreifolia*	Moraceae	Tree		√	
39	*Ficus exasperate*	Moraceae	Tree		√	
40	*Ficus mucosa*	Moraceae	Shrub		√	
41	*Ficus valis-choudae*	Moraceae	Tree		√	
42	*Ficus thoningii*	Moraceae	Tree		√	
43	*Flabellaria paniculata*	Malpighiaceae	Climber			√
44	*Flacourtia indica*	Flacourtiaceae	Tree			√
45	*Galisona parviflora*	Compositae	Herb			√
46	*Grevillea robusta*	Proteaceae	Tree			√
47	*Impatiens nana*	Balsaminaceae	Herb		√	
48	*Justicia betonica*	Acanthaceae	Herb			√
49	*Kyllinga elata*	Cyperaceae	Sedge		√	
50	*Lantana camara*	Verbenaceae	Shrub		√	√
51	*Leucaena glauca*	Fabaceae	Tree			√
52	*Mezoneuron angolense*	Caesalpiniaceae	Liana			√
53	*Markhamia lutea*	Bignoniaceae	Tree			√
54	*Mondia ecomuta*	Asclepideaceae	Liana			√
55	*Momordica foetida*	Cucurbitaceae	Liana			√
56	*Oplismenus hirtellus*	Graminae	Grass			√
57	*Pavetta stenocephala*	Rubiaceae	Shrub			√
58	*Panisetum mezianum*	Graminae	Grass			√
59	*Pergularia daemia*	Apocynaceae	Liana			√
60	*Panicetum parpureum*	Graminae	Grass			√
61	*Pillea adiantoides*	Adiantaceae	Climber			√
62	*Prunus africana*	Rosaceae	Tree			√
63	*Phragmites mauritianus*	Compositae	Grass	√	√	
64	*Polygonum senegalensis*	Polygonaceae	Grass		√	
65	*Raufolvia caffra*	Apocinaceae	Tree			√
66	*Rubia cordifolia*	Rubiaceae	Climber			√
67	*Rubus pinatus*	Rosaceae	Herb			√
68	*Rubus rosifolius*	Rosaceae	Herb			√
69	*Rothmania urcellifomis*	Rubiaceae	Shrub			√
70	*Spermacose laevis*	Rubiaceae	Herb			√
71	*Spilanthes filicaulis*	Compositae	Herb			√
72	*Sporobulus pyramidalis*	Graminae	Grass		√	√
73	*Sida cordifolia*	Malvaceae	Herb			√
74	*Smilax anceps*	Smillacaceae	Climber		√	√
75	*Solanecio angulatus*	Bignoniaceae	Climber			√
76	*Sorindeia madagascariensis*	Anacardiaceae	Tree			√
77	*Strychnos cocculoides*	Loganiaceae	Liana			√
78	*Syzigium cumini*	Myritaceae	Tree			√
79	*Suaeda monoica*	Chenopodiaceae	Shrub		√	
80	*Teclea symplifolia*	Rutaceae	Shrub			√
81	*Todalia asiatica*	Rutaceae	Shrub			√
82	*Trema orientalis*	Ulmaceae	Tree			√
83	*Trimeria grandifolia*	Flacourtiaceae	Tree			√
SN	**Species**	**Family**	**Growth Form**	**In Water Column**	**Wet Bank**	**Dry Bank**
84	*Turaea holstii*	Meliaceae	Tree			√
85	*Thelipteris confluens*	Thelypridaceae	Fern			√
86	*Tithonia diversifolia*	Bignoniaceae	Shrub			√
87	*Vangueria madagascariensis*	Rubiaceae	Tree			√
88	*Vernonia sabuligera*	Bignoniaceae	Shrub			√

3.2.2 The Upper Foothill Zone

The upper foothill zone vegetation composes 72 plant species with 65 terrestrial and seven aquatic/emergent species (Table 4).

Table 4 Plant Species of the Upper Foothill Zone of the Pangani River System

SN	Species	Family	Growth Form	In Water Column	Wet Bank	Dry Bank
1	*Abutilon mauritianum*	Malvaceae	Herb			√
2	*Acacia xanthoploea*	Menispermaceae	Tree		√	
3	*Achyranthes aspera*	Amaranthaceae	Herb		√	√
4	*Albizi glaberima*	Mimosaseae	Tree			√
5	*Adenia rumicifolia*	Caryophylaceae	Liana			√
6	*Argemone mexicana*	Papaveraceae	Herb			√
7	*Bombax rhodognaphalon*	Bombacaceae	Tree			√
8	*Brachiaria serrata*	Poaceae	Grass		√	√
9	*Celtis africana*	Ulmaceae	Tree			√
10	*Cassia floribunda*	Papilionaceae	Shrub			√
11	*Cenna spectabilis*	Papilionaceae	Tree			√
12	*Commelina beghalensis*	Commelinaceae	Herb		√	√
13	*Cissus integrifolia*	Vitaceae	Climber			√
14	*Cissus quadrangularis*	Vitaceae	Climber			√
15	*Cissus rotundifolia*	Vitaceae	Climber			√
16	*Cissus cordifolia*	Vitaceae	Climber			√
17	*Cupsicum frutescens*	Piperaceae	Shrub			√
18	*Clausena anisata*	Rutaceae	Shrub			√
19	*Comiphora pteleifolia*	Burseraceae	Tree			√
20	*Cussonia arborea*	Araliaceae	Tree			√
21	*Cynodon lefuense*	Poaceae	Grass			√
22	*Cyperus distans*	Cyperaceae	Sedge	√	√	
23	*Dactyloctenium geminatum*	Poaceae	Grass			√
24	*Drypetes gerardii*	Euphorbiaceae	Tree			√
25	*Drypetes natalensis*	Euphorbiaceae	Tree			√
26	*Englerophytum natalense*	Sapotaceae	Shrub			√
27	*Erythroccoca bongensis*	Euphorbiaceae	Sedge			√
28	*Euphorbia nyikae*	Euphorbiaceae	Tree			√
29	*Euphorbia tirucalli*	Euphorbiaceae	Tree			√
30	*Ficus capreifolia*	Moraceae	Tree			√
31	*Ficus exasperata*	Moraceae	Tree		√	
32	*Ficus sansibarica ssp sansibarica*	Moraceae	Tree			√
33	*Ficus sur*	Moraceae	Tree		√	
34	*Ficus thoningii*	Moraceae	Climber			√
35	*Ficus valischoudae*	Balsaminaceae			√	
36	*Ficus ingens*	Thelypridaceae	Tree			√
37	*Glycine wightii*	Leguminosae	Climber			√
38	*Grewia mollis*	Tiliaceae	Shrub			√
39	*Grewia conocarpa*	Tiliaceae	Shrub			√

SN	Species	Family	Growth Form	In Water Column	Wet Bank	Dry Bank
40	*Haplocoelium foliolosum*		Tree			
41	*Justicia glabra*	Acanthaceae	Herb			√
42	*Kanahia laniflora*	Compositae	Herb			√
43	*Kigelia africana*	Bignoniaceae	Tree			√
44	*Lantana camara*	Verbenaceae	Shrub			√
45	*Leonotis mollisma*	Lamiaceae	Sedge			√
46	*Leucaena glauca*	Fabaceae	Tree			√
47	*Panicum maximum*	Graminae	Grass			√
48	*Manihot esculenta*	Euphorbiaceae	Shrub			√
49	*Opuntia vulgaris*	Cactaceae	Shrub			√
50	*Psychotria riparia*	Bignoniaceae	Shrub			√
51	*Passiflora edulis*	Passifloraceae	Climber			√
52	*Pennisetum mezianum*	Poaceae	Grass			√
53	*Pluchea dioscoridis*	Compositae	Shrub			√
54	*Polygonum senegalensis*	Polygonaceae	Herb		√	
55	*Rauvolfia caffra*	Apocynaceae	Tree			√
56	*Ricinus communis*	Euphorbiaceae.	Shrub			√
57	*Sensevieria ehrenbergii*	Ruscaceae	Herb			√
58	*Setaria homonyma*	Poaceae	Grass			√
59	*Solanum incanum*	Solanaceae	Shrub			√
60	*Suaeda monoica*	Chenopodiaceae	Shrub		√	
61	*Sorindeia madagascariensis*	Myrtaceae	Tree			√
62	*Tarbenaemontana pachysiphon*	Caesalpiniaceae	Tree			√
63	*Tabernaemontana holstii*	Apocynaceae	Tree		√	√
64	*Talinum portulacifolium*	Portulacaceae	Herb			√
65	*Tithonia diversifolia*	Asteraceae	Shrub			√
66	*Teclea nobilis*	Rutaceae	Shrub			√
67	*Teclea simplicifolia*	Rutaceae	Shrub			√
68	*Trichilia emetica*	Meliaceae	Tree			√
69	*Turraea holstii*	Meliaceae	Tree			√
70	*Vangueria madagascariensis*	Rubuaceae	Shrub			√
71	*Vernonia amygdalina*	Bignoniaceae	Shrub		√	√
72	*Withania somnifera*	Solanaceae	Herb			√

3.2.3 The Lower Foothill Zone

The lower foothill zone is the most species rich consisting of 104 plant species out of which 45 (43%) are aquatic/emergents. Note that the wet bank species are grouped into the aquatic species/emergents. As would be the case for the aquatic plant species the genus *Cyperus* is the most dominant (Table 9).

Table 5 Species of the lower foothill zone of the Pangani River system

SN	Species	Family	Habit	In Water Column	Wet Bank	Dry Bank
1	*Albizia glaberrima*	Mimosaceae	Tree			√
2	Albizia gummifera	Mimosaceae	Tree			√
3	*Acacia xanthoploea*	Mimosaseae	Tree		√	
4	*Acacia robusta*	Mimosaseae	Tree			√
5	*Acrostichum aureum*	Adiantaceae	Fern		√	
6	*Acalypha omata*	Euphorbiaceae	Herb			√
7	*Acalypha fruticosa*	Euphorbiaceae	Herb			√
8	*Abutilon mauritianum*	Malvaceae	Herb			√
9	*Achyranthes aspera*	Amaranthaceae	Herb			√
10	*Asystasia gangetica*	Acanthaceae	Herb			√
11	*Azidarachta indica*	Meliaceae	Tree			√
12	*Barringtonia racemosa*	Lecythidaceae	Shrub		√	
13	*Cassia floribunda*	Papilionaceae	Shrub			√
14	*Cassia mimosoides*	Papilionaceae	Herb			√
15	*Ceropegia distincta*	Asclepiadaceae	Climber			√
16	*Chaetachme aristata*	Ulmaceae	Shrub			√
17	*Chloris gayana*	Poaceae	Grass			√
18	*Cisampelos pareira*	Menispermaceae	Climber			√
19	*Commelina beghalensis*	Commelinaceae	Herb		√	√
20	*Cordia sinensis*	Boraginaceae	Tree			√
21	*Culcasia esculenta*	Rutaceae	Herb			√
22	*Cynodon dactylon*	Poaceae	Grass		√	√
23	*Cynodon articulatus*	Poaceae	Grass		√	√
24	*Cynodon lemfuense*	Poaceae	Grass		√	√
25	*Cyperus alticulatus*	Cyperaceae	Sedge		√	√
26	*Cyperus distans*	Cyperaceae	Sedge	√	√	
27	*Cyperus exaltatus*	Cyperaceae	Sedge	√	√	
28	*Cyperus payrus*	Cyperaceae	Sedge	√	√	
29	*Cyperus rotundus*	Cyperaceae	Sedge	√	√	
30	*Dactyloctenium germinatum*	Poaceae	Grass			√
31	*Digitaria milanjiana*	Poaceae	Grass			√
32	*Echinochloa scabra*	Poaceae	Grass			√
33	*Ehretia amoena*	Boraginaceae	Tree			√
34	*Eleis guineense*	Fabaceae	Tree		√	
35	*Eragrostis aspera*	Poaceae	Grass		√	√
36	*Euclea natalensis*	Ebenaceae	Shrub			√
37	*Ficus sur*	Moraceae	Tree		√	
38	*Ficus thoningii*	Moraceae	Tree		√	
39	*Ficus capreifolia*	Moraceae	Tree		√	

SN	Species	Family	Habit	In Water Column	Wet Bank	Dry Bank
40	*Ficus exasperata*	Moraceae	Tree		√	
41	*Hibiscus canabinus*	Malvaceae	Herb		√	√
42	*Hibiscus esculenta*	Malvaceae	Herb			√
43	*Hibiscus micranthus*	Malvaceae	Herb			√
44	*Fimbuistylis feruginea*	Cyperaceae	Sedge	√	√	
45	*Flagellaria guineensis*	Flagellariaceae	Climber			√
46	*Flagellaria virosa*	Flagellariaceae	Sedge			√
47	*Garcinia livingstonei*	Clusiaceae	Tree			√
48	*Gardenia transvenulosa*	Rubiaceae	Shrub			√
49	*Harrisonia abyssinica*	Rutaceae	Sedge			√
50	*Heliotropium indicum*	Boraginaceae	Herb			√
51	*Hyparrhenia filipendula*	Poaceae	Grass			√
52	*Ipomoea pescaprae*	Convolvulaceae	Climber		√	√
53	*Crinum kirkii*	Amaryllidaceae	Herb		√	√
54	*Kyllinga elata*	Cyperaceae	Sedge		√	
55	*Ludwigia jussiaeoides*	Onagraceae	Herb		√	
56	*Leersia hexandra*	Compositae	Grass	√		
57	*Leonotis mollisma*	Lamiaceae	Herb		√	√
58	*Macrula africana*	Moraceae	Sedge		√	
59	*Mascarenhasia arborescens*	Apocynaceae	Liana			√
60	*Maytenus mossambicensis*	Celastraceae	Tree			√
61	*Melanthera scandens*	Asteraceae	Herb			√
62	*Mikania cordata*	Compositae	Liana		√	
63	*Mimosa pigra*	Gramineae	Liana		√	
64	*Mimusopsis fruticosa*	Sapotaceae	Tree			√
65	*Momordica foetida*	Cucurbitaceae	Liana			√
66	*Mucuna pruriens*	Fabaceae	Liana			√
67	*Mondia ecomuta*	Asclepideaceae	Liana			√
68	*Musa sp*	Musaceae.	Shrub		√	√
69	*Nymphia retusa*	Gramineae	Herb	√		
70	*Opilia cettidifolia*		Liana		√	√
71	*Panicum maximum*	Poaceae	Grass		√	√
72	*Parkia filicoidea*	Fabaceae	Tree		√	√
73	*Paullinia pinnata*	Sapindaceae			√	√
74	*Paspalum scrobiculatum*	Poaceae	Grass		√	√
75	*Pennisetum purpureum*	Poaceae	Grass		√	√
76	*Phoenix reclinata*	Palmae	Sedge		√	√
77	*Phragmites mauritianus*	Compositae	Grass	√		
78	*Plectranthus kilimandscharica*	Lamiaceae	Herb			√
79	*Pluchea dioscoridis*	Compositae	Shrub			√
80	*Polygonum senegalese*	Polygonaceae	Herb		√	
81	*Rauvolfia caffra*	Apocynaceae	Tree			√
82	*Rynchosia micrantha*	Fabaceae	Climber			√
83	*Ricinus communis*	Euphorbiaceae	Shrub			√
84	*Rinorea eliptica*	Moraceae	Shrub			√

	Species	Family	Habit	In Water Column	Wet Bank	Dry Bank
85	*Saba comorensis*	Apocynaceae	Liana			√
86	*Saccharum officinarum*	Poaceae	Herb			√
87	*Sapindus saponaria*	Sapindaceae	Tree			√
88	*Sclerocarya birrea ssp caffra*	Anacardiaceae	Tree			√
89	*Sesbania sesban*	Leguminosae	Shrub			√
90	*Setaria homonyme*	Graminae	Shrub			√
91	*Sorindeia madagascariensis*	Anacardiaceae	Tree			√
92	*Solanum incanum*	Solanaceae	Herb			√
93	*Sporobolus consimilis*	Graminae	Grass		√	√
94	*Sporobolus pyramidalis*	Graminae	Grass		√	√
95	*Spirostachys africana*	Euphorbiaceae	Tree			√
96	*Suaeda monoica*	Chenopodiaceae	Shrub		√	
97	*Syzygium cumini*	Myritaceae	Tree			√
98	*Trichilia emetica*	Meliaceae	Tree			√
99	*Turraea holstii*	Meliaceae	Tree			√
100	*Typha capensis*	Typhaceae	Sedge			√
101	*Urochloa panicoides*	Poaceae	Grass			√
102	*Urtica massaica*	Urticaceae	Herb		√	√
103	*Vernonia hildebrandtii*	Leguminosae	Shrub		√	√
104	Zea mays	Graminae	Shrub		√	√

3.2.4 The Rejuvenated Bedrock Cascade

This zone has a species richness of 17 of which two species are dry bank while the others are either aquatic or wet bank species (Table 6).

Table 6 Species of the Rejuvenated Bedrock Cascade zone of the Pangani River system

SN	Species	Family	Habit	In Water Column	Wet Bank	Dry Bank
1	*Artocarpus integrifolius*	Moraceae	Tree			√
2	*Cocos nucifera*	Arecaceae	Tree		√	
3	*Cynodon lemfuens*	Poaceae	Grass			√
4	*Cyperus alticulatus*	Cyperaceae	Sedge		√	
5	*Cyperus rotundus*	Cyperaceae	Sedge		√	
6	*Dacyloctenium germinatum*	Poaceae	Grass		√	√
7	*Digitaria milanjiana*	Poaceae	Grass		√	√
8	*Echnocloa scabra*	Poacea	Grass		√	√
9	*Eleis guineensis*	Palmae	Tree		√	√
10	*Ficus sur*	Moraceae	Tree		√	
11	*Ipomea pescapreae*	Convolvulaceae	Herb		√	√
12	*Kanahia laniflora*	Asclepiadaceae	Herb		√	√
13	*Leersia hexandra*	Compositae	Grass	√	√	
14	*Panicum maximum*	Poaceae	Grass		√	√
15	*Panicum tricocladum*	Poaceae	Grass		√	√
16	*Phragmites mauritianus*	Poaceae	Grass	√		
17	*Sesbania sesban*	Fabaceae	Shrub			√

3.2.5 The Mature Lowland River

About 35 species were identified in this zone of which two are terrestrial and 12 are aquatic-wet bank species (Table 7).

Table 7 Species of the mature lowland zone of the Pangani River system

SN	Species	Family	Habit	In Water Column	Wet Bank	Dry Bank
1	*Acacia polyacantha*	Mimosaceae	Tree			√
2	*Asystasia gangetica*	Acanthaceae	Herb			√
3	*Barringtonia racemosa*	Lecythidaceae	Tree		√	
4	*Bombax rhodognaphalon*	Bombacaceae	Tree			√
5	*Bridelia cathartica*	Euphorbiacea	Tree		√	√
6	*Cassia mimosoides*	Caesalpiniaceae	Herb			√
7	*Cissampelos pareira*	Menispermaceae	Climber		√	√
8	*Commelina beghalensis*	Commelinaceae	Herb		√	√
9	*Combretum pentagonum*	Combretaceae	Shrub			√
10	*Corchorus aestuans*	Tiliaceae	Herb			√
11	*Crotalaria labumifolia*	Papilionaceae	Herb		√	√
12	*Cyperus distans,*	Cyperaceae	Sedge	√	√	
13	*Dichanthium caricosum*	Poaceae	Grass		√	√
14	*Ficus capreifolia*	Moraceae	Tree		√	
15	*Ficus exasperata*	Moraceae	Tree		√	
16	*Ficus sur*	Moraceae	Tree		√	
17	*Hyparrhenia filipendula*	Poaceae	Grass		√	√
18	*Kanahia laniflora*	Asclepiadaceae	Herb		√	
19	*Mangifera indica*	Anacardiaceae	Tree			√
20	*Mascarenhasia arborescense*	Apocynaceae	Liana			√
21	*Mikania cordata*	Asteraceae	Liana			√
22	*Mucuna pruriens*	Leguminosae	Liana			√
23	*Musa sp*	Musaceae	Shrub			√
24	*Ormocarpum kirkii*	Fabaceae	Sedge			√
25	*Nymphia retusa*	Gramineae	Herb			√
26	*Parkia filicoidea*	Fabaceae	Tree			√
27	*Paspalum scrobiculatum*	Poaceae	Grass			√
28	*Pluchea dioscoridis*	Compositae	Shrub			√
29	*Ricinus communis*	Euphorbiaceae	Shrub			√
30	*Rottboellia exaltata*	Poaceae	Grass			√
31	*Senna siamea*	Caesalpinioideae	Tree			√
32	*Stereospermum kunthianum*	Bignoniaceae	Grass			√
33	*Thespesia danis*	Malvaceae	Shrub			√
34	*Thevetia peruviana*	Apocynaceae	Fern			√
35	*Vigna unguiculata*	Fabaceae	Climber			√

Of the four zones, the lower foothill zone was the most species rich in terms of total numbers and aquatic plant species, while the upper foothill was the most species rich in terms of terrestrial plant species.

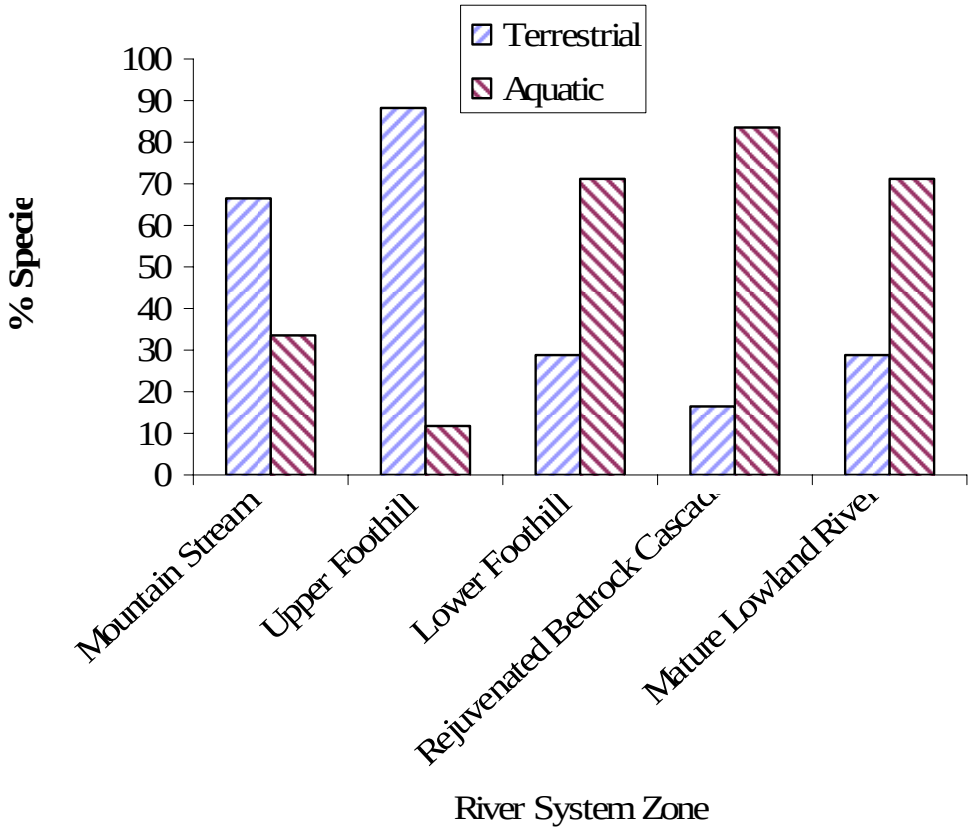

Figure 4 **Distribution of terrestrial and aquatic plant species in the different zones of the Pangani River Basin**

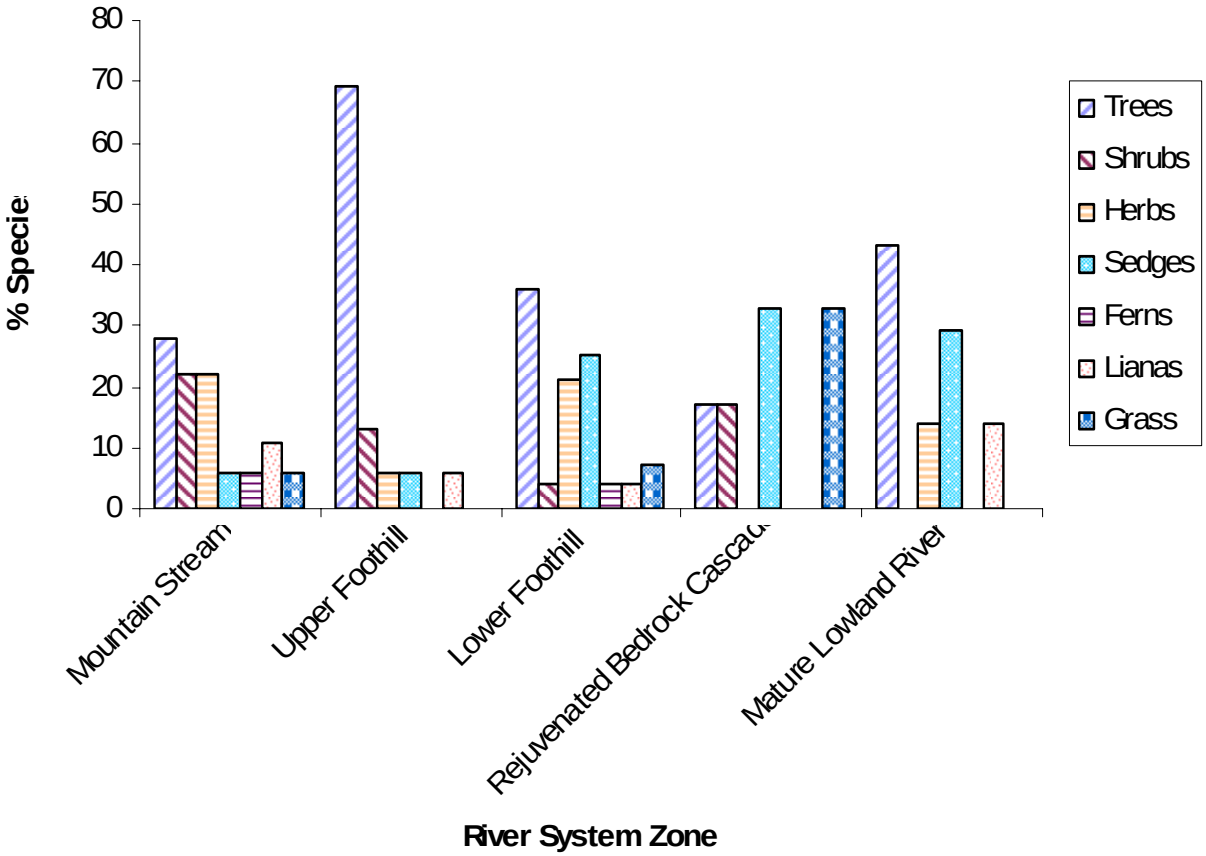

Figure 5 **Distribution of different plant growth forms in the different zones of the Pangani River System**

3.2.6 The Estuary

The principal vegetation types of the Pangani estuary are sedges, palms and Mangroves. Sedges and lilies are dominant in the upper reaches, while the middle and lower reaches are dominated by palms and mangroves respectively. There seems to be a strong zonation in these communities up the length of the estuary, presumably a function of the salinity distribution in the system. Mangroves of the Pangani estuary however make up only a small proportion of the total mangrove forest area in Tanzania. The mangrove species found in the Pangani estuary are listed in Table 12 (IUCN, 2006, Munishi 2007). Cocos nucifera is also a part of the estuary zone on high grounds where the soil is not saline

Table 8 Species of the Estuary zone of the Pangani River system

SN	*Species*	Family	Habit	In Water	Wet bank	Dry bank
1	*Avicenia marina*	Acanthaceae	Tree	√	√	
2	*Bruguera gymnorrhza*	Rhizophoraceae	Tree	√	√	
3	*Ceriops tagal*	Rhizophoraceae	Tree	√	√	
4	*Herritiera littoralis*	Sterculiaceae	Tree	√	√	
5	*Lumnitzera racemosa*	Combretaceae	Tree	√	√	
6	*Rhizophora mucronata*	Rhizophoraceae	Tree	√	√	
7	*Sonneratia alba*	Sonneratiaceae	Tree	√	√	
8	*Xylocarpus grantum*	Meliaceae	Tree	√	√	
9	*Cocos nucifera*	Palmae	Tree		√	√

3.3 Lateral Distribution of Riverine Vegetation

The lateral distribution of the riverine communities described here is the distribution of the plant communities/species along the cross section of the river at specific sites selected to represent specific characteristics of the Pangani system. These zones represent the mountain stream, the upper foothill, the lower foothill, rejuvenated bedrock cascade, mature lowland river and the estuary.

3.3.1 Mountain Stream Zone

This zone is represented by Nduruma and Ona Rivers. This was chosen following the categories developed by IUCN (2006). The riparian width at Nduruma is 30 m and 5 m on the right and left hand bank respectively while on the Ona River it is relatively wide (70 m and 80 m on the right and left hand banks respectively). The riparian zone on the Nduruma River is critically modified through removal of natural vegetation, encroachment by exotic vegetation and bank erosion. On the other hand the riparian zone of the Ona River is relatively intact with no encroachment.

Both rivers can be described as having a straight, single thread channel, with mixed bedrock and alluvial channel type. The Nduruma River substratum is dominated by cobble and boulder while that of Ona river is dominated by bedrock and boulder. The reach type on both rivers is pool-rapid though the predominant reach type on Ona River is bedrock fall. The river make up on the Nduruma River can be summarized as a mix of riffle/rapid and run while on the Ona River it rapid and run in the wet season and a mix of riffle/rapid, run and pool in the dry season.

Trees, shrubs, sedges and grasses are represented in all the two rivers. Typically, sedges occur closer to the stream in more or less aquatic conditions while trees occur in more terrestrial conditions up the banks on the wet bank and dry bank habitats. *Adenia rumicifolia, Abutilon mauritianum* and *Albizia schimperana* are the most common dry bank species while *Ficus capreifolia, Ficus exasperata, Ficus mucosa, Ficus valischoudae,* and *Ficus thoningii* are the most dominant wet bank species. The aquatics in this zone include *Kyllinga elata, Phragmites mauritianus and Polygonum senegalensis.*

3.3.2 Upper Foothill Zone

This zone is represented by points along the Pangani system at Kikuletwa, Himo and Muraini (Mvuleni) Rivers. The riparian widths range from 10 m on the Himo River to 200 m on the Muraini (Mvuleni) River. The riparian zones at these points were critically modified on the Kikuletwa River while there are moderate modifications on Himo and Muraini Rivers. The modification results mainly from removal of natural vegetation, encroachment by exotic vegetation and river bank erosion though encroachment by exotic vegetation was not so evident in the Muraini River is relatively limited. Some areas on the Kikuletwa River are completely bare due to vegetation removal and livestock watering.

The Kikuletwa River has a multiple thread, sinuous channel, located within a broader floodplain while Himo River and Muraini River have straight, single thread channels. The substratum on the Kikuletwa River is a mixed bedrock and alluvial dominated by gravel. On the Himo River the substratum is dominated by cobble and boulders while the Muraini River substratum is alluvial dominated by cobble. The river makeup for Kikuletwa is run during the wet season becoming a mix of riffle/rapid, run and pool during the dry season. The makeup on the other rivers is a mix of riffle/rapid run and pool (IUCN 2006).

Trees, shrubs, reeds, sedges and grasses are represented in all rivers though sedges are less abundant at Himo River. At Muraini River the vegetation has a closed canopy dominated by Fig trees (*Ficus sp*) and minimum undergrowth of herbaceous plants.

The river make up is important determinant of what vegetation type and species would occur in the different sections. On riffles one would expect to find some rooted aquatic plants as there is a good possibility of soil and debris accumulation. On the other hand submerged aquatic plants are likely to occur on the pool section while on rapids and runs one would not expect much vegetation in the water column. The wet bank vegetation would thrive better on the pool sections due to prolonged water periods during the dry season when all other sections may have dried out especially in the case of ephemeral rivers.

Where the river is a pool one would expect to find more aquatic plants such as *Cyperus distans, Kanahia laniflora* and *Polygonum senegalensis* among others while on the riffle section one would expect more of the wet and dry bank species like *Acacia xanthophloea Ficus exasperata* and *Ficus sur* and *Albizi glaberima, Sorindeia madagascariensis Psychotria riparia* and *Celtis africana* respectively.

3.3.3 Lower Foothill Zone

This zone is represented by Kikuletwa River upstream of Nyumba ya Mungu dam below Tanzania Planting Company, Ruvu River at Kifaru, upstream of bridge, Pangani at Kirua swamp, Pangani River at Mkalamo village approximately 500 m upstream of bridge at bedrock rapid, Pangani river at Jambe village, 50 m, above confluence with outflow from the Pangani Falls

Hydropower Station, Mkomazi River at Bendera, downstream of Kalimawe Dam and Luengera River at Kwamndolwa, old Korogwe.

Both sites have moderate to critical modifications resulting from removal of natural vegetation and river bank erosion. The riparian width varies from 5 m to over 100 m. In some cases the riparian zone is interfered by floodplain. With exception of Mkomazi River where there is extensive encroachment by exotic vegetation and some terrestrial plants the other sites have very limited encroachment. Trees, shrubs, reeds, sedges and grasses are represented with reeds and sedges dominating at the Mkomazi site.

The Kikuletwa River at this site has a multiple thread, sinuous channel, located within a broader floodplain. It has a mixed bedrock and alluvial channel with gravel as the dominant substratum. The Ruvu, Pangani, Mkomazi and Luengera Rivers at this zone have a straight, single thread channels. Ruvu River has an alluvial channel type, dominated by silt and clay, the Pangani has alluvial channel with silt, clay and sand as the dominant substrata, Mkomazi has sand as dominant substrata and the Luengera River has sand as the dominant substratum

The reach type for Kikuletwa is flat bedrock with a relatively smooth bed and no significant falls or rapids though it could also be considered regime. The summarized river make up is a run only in the wet season, becoming a mix of riffle/rapid, run and pool in the dry season. The rich type for Ruvu, Pangani Mkomazi and Luengera are regime, and the river make up is a run only in the wet season, becoming a mix of riffle and run in the dry season for Kikuletwa, run and pool for Pangani, run for Mkomazi and pool for Luengera. Dry and wet bank species like A*lbizia glaberrima, Sorindeia madagascariensis Trichilia emetica Ficus sur, Ficus capreifolia* and *Acacia xanthoploea* would be more common because of rapid water movement in most of its sections. Some aquatic species such as *Cyperus alticulatus, Cyperus exaltatus and Cyperus papyrus* would be expected where the river is mostly a pool during the different seasons

3.3.4 Rejuvenated Bedrock Cascade Zone

The zone is represented by Pangani River downstream of Hale town. The zone is seriously modified because of removal of natural vegetation, and river bank erosion. Encroachment by exotic vegetation is limited. The riparian width is 5 m on the right hand bank and 5 m on the left hand bank. The river has a straight, multiple thread channels, although the side channel is relatively small compared to the main channel. It has a bedrock channel, with pools alternating with bedrock rapid areas making the reach type pool-rapid. The summarized river make up is a rapid and run. Trees, shrubs, sedges and grasses are represented. The riparian vegetation is severely exploited and the impact from rural development on vegetation is high. This type of river makeup would have a more abundant wet bank plant species due to fast water movement in most of its sections which makes the river bank drier and especially during the dry season. Species such as *Cyperus alticulatus, Cyperus rotundus* which are semi aquatic-wet bank may be found towards the water column while the real wet bank species would include *Ficus sur*

3.3.5 Mature Lowland River Zone

This section is represented by the Pangani River above the confluence of the point at which the outflow from the Pangani Falls Hydropower Station joins the river. The riparian width is 70 m on the right hand bank and 5 m on the left hand bank. There is limited encroachment by exotic vegetation in this zone and trees, shrubs, sedges and grasses are represented.

The river has a straight, single thread channel, with a bedrock channel. The reach type is pool-rapid and the summarized river make-up is a mix of riffle/rapid, run and pool. This mixture of river make up is expected to allow a wide variety of plant species to occur from sub merged

aquatics on the pool section such as *Cyperus distans, Kanahia laniflora* and *Cyperus rotundus* to wet and dry bank species such as Ficus *sur, Acacia polyacantha, Markhamia cordata and Barringtonia racemosa.*

3.3.6 The Estuary

The major vegetation type on the Pangani estuary is mangroves and mangroves are often considered the most important component of estuarine vegetation. Mangroves are known to be salt-tolerant tree species that occur on tropical and subtropical coastlines, especially in sheltered bays and around river mouths. Eight species of mangrove are reported (Kamugisha *et al*., 2006) to occur in the Pangani basin, including *Avicernia marina, Bruguira gymnorrhza, Herritiera littoralis, Lumnitzera racemosa, Rhizophora mucronata, Sonneratia alba, Xylocarpus granatum and Ceriops tagal.* Further in raised grounds around the estuary where soil conditions are not too salty *Cocos nucifera* is a common plant species which is normally cultivated.

The mangrove forests on the Pangani estuary (3 800 ha) however account for only a small proportion of the total mangrove area in Tanzania (~108 000 ha) (Wang et al., 2003) but are nonetheless important for the ecology of the estuary and for sustaining fish and shrimp production in the neighboring coastal areas.

3.4 Azonal Vegetation: Wetlands and Floodplains

The wetland and flood plain areas are represented in various sections of the basin. Most notable areas are the Kirua swamp at the lower foothill section downstream of the Nyumba ya Mungu. Many of these areas are still inundated though at lower frequency than it used to be (IUCN 2006). There are various species occurring in this habitats (Table 9)

Table 9 Plant species of the wetlands and floodplain vegetation

Species	Family	Habit	In Water	Wet bank	Dry bank
Acacia xanthophloes	Mimosaceae	Tree		√	√
Dactyloctenium geminatum	Poaceae	Grass	√	√	
Cyperus alticulatus	Cyperaceae	Sedge	√	√	
Cyperus exaltatus	Cyperaceae	Sedge	√	√	
Cyperus distans	Cyperaceae	Sedge	√	√	
Typha capensis	Typhaceae	Sedge	√	√	
Phragmites mauritianus;	Compositae	Herb	√	√	
Ludwigia jussiaeoides	Onagraceae	Herb	√	√	
Pistia stratiotes	Araceae	Herb	√	√	
Eichhornia crassipes	Pontederiaceae	Herb	√	√	
Nymphaea retusa	Mimosacea	Herb	√	√	

3.5 Changes from Natural Vegetation and its Drivers

Different zones of the rivers show changes from natural vegetation cover to modified vegetation especially along the riparian zones. These changes are a result of human disturbances which lead to encroachment by exotic species. Areas which are severely disturbed normally become prone to exotic invasions as a result possible changes from their natural states. Exotic vegetation invasion is always taken as a major indicator of changes from natural to artificial habitats in the different sections/zones of the basin. Most of these changes seem to be human induced though in some cases natural regeneration of exotics would occur as a result of degradation of natural

vegetation giving the exotics a more competitive ability. Exotic species therefore exclude natural vegetation due to vigorous growth at a rate higher than the indigenous vegetation.

Some areas were observed to be critically modified as a result of encroachment by exotic species resulting from removal of natural regeneration and bank erosion. Areas like the Nduruma River (Mountain Stream Zone), encroachment by exotic vegetation was widespread and smaller areas were invaded by terrestrial plants. At Kikuletwa River (Upper Foothill zone), the riparian vegetation is critically modified because of the decrease of indigenous vegetation from the riparian zone, exotic vegetation encroachment and bank erosion though the impact on the riparian vegetation is localized. At Ona River, a Mountain Stream the riparian zone at the sampling point was almost bare due to removal of riparian vegetation and livestock watering though encroachment by exotics was limited. Other area that showed serious modification of the riparian ecosystem include the Ruvu River (lower foothill zone), Pangani River (the rejuvenated bedrock cascade and mature lowland river zones) and the Mkomazi River (a lower foothill zone). Some areas were moderately modified and not severely encroached by exotic vegetation including Muraini (Mvuleni) River (an upper foothill zone) and some parts of the Pangani River (a lower foothill zone)

4.0 ECOLOGICALLY IMPORTANT SPECIES

4.1 Indicator species

An indicator plant is usually plants that grow in some specific environment, allowing an assessment of soil and other conditions in a place. The usefulness of the concept of indicator species is that they can be used for biomonitoring of community or ecosystem change. Therefore, it is possible to assess the physiochemical characteristics of a site based upon the species composition present, which is very useful for monitoring change and detecting the cause(s) of change. Some species are indicators of water logged/flooded, moist/wetland conditions while others are indicators of salty environments and grow well in areas with high soil salt content. The mangrove vegetation are indicators of salty conditions where river water mixes with sea water and thus an indicator of estuarine conditions on river mouths and deltas On the other hand some plants are indicators of coastal warm climates and areas with high water table while others are indicators of dry/semi arid conditions. About 33 plant species in the Pangani basin were identified as indicators of flooded, saturated or salty conditions for part or most of the year (Table 10)

Table 10 Indicator Plant Species in the Pangani River Basin

SN	Species	Indication
1	*Cyperus alticularis*	Moist, saturated, water logged conditions
2	*Cyperus exaltatus*	Moist, saturated, water logged conditions
3	*Drymaria cordata*	Moist, saturated, water logged conditions
4	*Acrostichum aureum*	Moist, saturated, water logged conditions
5	*Fimbristylis feruginea*	Moist, saturated, water logged conditions
6	*Ludwigia jussiaeoides*	Moist, saturated, water logged conditions
7	*Hyphaene* spp (Mikoche)	Moist, saturated, water logged conditions
8	*Cyperus rotundus*	Moist, saturated, water logged conditions
9	*Cyperus distans*	Moist, saturated, water logged conditions
10	*Cyperus papyrus*	Moist, saturated, water logged conditions
11	*Costus afer*	Moist, saturated, water logged conditions
12	*Phragmites mauritianus*	Moist, saturated, water logged conditions
13	*Nymphae retusa*	Moist, saturated, water logged conditions
14	*Polygonum senegalense*	Moist, saturated, water logged conditions
15	*Makuruwila*	Moist, saturated, water logged conditions
16	*Leersia hexandra*	Moist, saturated, water logged conditions
17	*Typha* sp.	Moist, saturated, water logged conditions
18	*Kyllinger ellata*	Moist, saturated, water logged conditions
19	*Kanahia laniflora*	Moist, saturated, water logged conditions
20	*Phoenix reclinata* (Kindu)	Moist, saturated, water logged conditions
21	*Ficus* sp.	Moist, saturated, water logged conditions
22	*Euphorbia sp (Minyaa/ Miaa*	Dry/semi arid conditions
23	*Suaeda monoic*	Salty conditions
24	*Avicenia marina a*	Salty conditions
25	*Bruguira gymnorrhza*	Salty conditions
26	*Herritiera littoralis*	Salty conditions
27	*Lumnitzera racemosa*	Salty conditions
28	*Rhizophora mucronata*	Salty conditions
29	*Sonneratia alba*	Salty conditions
30	*Xylocarpus granatum*	Salty conditions
31	*Ceriops tagal*	Salty conditions
32	*Cocos nucifera (minazi)*	Warm climates, sandy soil conditions
33	*Milicia excelsa*	Lowland forests, high water table

4.2 Keystone species

A keystone species is a species that has a disproportionate effect on its environment relative to its abundance. An ecosystem may experience a dramatic shift if a keystone species is removed, even though that species was a small part of the ecosystem in terms of biomass or productivity. It has become a very popular concept in conservation biology. Keystone species affect ecosystem composition and structure in fundamental ways through trophic interactions (food webs and food chains), such that the removal of a keystone species has a disproportionate effect on the ecosystem by causing the local extinction of several to many other species, possibly leading to collapse of the ecosystem of which it is a part. The means by which Keystone Species affect ecosystem structure is through positive and negative effects on species that feed on, or are fed on by, other species in the community or ecosystem. The species that make up the mangrove ecosystem form a mix of keystone species that are important for breeding and survival of key marine and terrestrial organisms Table 11). Mangroves (Mikoko) are often considered the most important component of estuarine vegetation as they serve to trap landed-derived debris, sediment and suspended particulate matter carried down by rivers increasing the food required by benthic invertebrates. They are extremely productive ecosystems supplying food for different types of organisms and function as important feeding and nursery areas for a variety of invertebrates, fish and birds. On the other hand the river key stone species in wetlands and flood plains are important primary producers and are food source for grazing animals

Table 11 Keystone Plant Species of the Pangani River Basin

SN	Species	Use/Location
1	*Avicenia marina*	Breeding of fish in estuaries, construction material
2	*Bruguira gymnorrhza*	Breeding of fish in estuaries, construction material
3	*Herritiera littoralis*	Breeding of fish in estuaries, construction material
4	*Lumnitzera racemosa*	Breeding of fish in estuaries, construction material
5	*Rhizophora mucronata*	Breeding of fish in estuaries, Construction material
6	*Sonneratia alba*	Breeding of fish in estuaries, construction material
7	*Xylocarpus granatum*	Breeding of fish in estuaries, construction material
8	*Ceriops tagal*	Breeding of fish in estuaries, construction material
9	*Cyperus alticularis*	Fish breeding, food for aquatic animals, fodder for livestock
10	*Cyperus exaltatus*	Fish breeding, food for aquatic animals, fodder for livestock
11	*Drymaria cordata*	Fish breeding, food for aquatic animals, fodder for livestock
12	*Acrostichum aureum*	Fish breeding, food for aquatic animals, fodder for livestock
13	*Fimbristylis feruginea*	Fish breeding, food for aquatic animals, fodder for livestock
14	*Ludwigia jussiaeoides*	Fish breeding, food for aquatic animals, fodder for livestock
15	*Hyphaene* spp (Mikoche)	Fish breeding, food for aquatic animals, fodder for livestock
16	*Cyperus rotundus*	Fish breeding, food for aquatic animals, fodder for livestock
17	*Cyperus distans*	Fish breeding, food for aquatic animals, fodder for livestock
18	*Cyperus papyrus*	Construction, Fish breeding, food for aquatic animals,

4.3 Ecosystem engineers

Ecosystem engineers are organisms that create, modify and maintain habitats. Ecosystem engineering can alter the distribution and abundance of large numbers of plants and animals, and significantly modify biodiversity. An ecosystem engineer affects ecosystem composition and structure through its effects on the flow of resources other than food. Therefore, an ecosystem engineer affects the structure of an ecosystem through increasing or decreasing the relative abundance or concentration of a resource such as a plant nutrient or a substance that is detrimental to the performance of organisms or groups of organisms. Some plants are able to perform this function in the Pangani basin. Such plants include nitrogen fixers and lianas among others. Among the ecosystem engineers in the Pangani basin are lianas such as *Adenia rumicifolia, Mezoneuron angolense,* and *Mikania cordata.* Lianas (woody vines) are autogenic engineers as when lianas grow through a forest canopy, they connect trees together, forming arboreal pathways that monkeys and other animals can use to travel without having to descend to the ground (Charles-Dominique 1971; Charles-Dominique *et al.*, 1981). The ecosystem engineers that are nitrogen fixers which increase nutrients in the ecosystem and include *Sesbania sesban*. Mangrove vegetation and its species (A*vicenia marina, Bruguira gymnorrhza, Herritiera littoralis, Lumnitzera racemosa, Rhizophora mucronata, Sonneratia alba, Xylocarpus granatum and Ceriops tagal)* are also considered ecosystem engineers as they form an environment which is an important habitat for spawning and breeding of other organisms including fish and other marine organisms.

5.0 SOCIO - ECONOMICALLY IMPORTANT PLANT SPECIES

5.1 Food plants

Table 12 shows the plant species that were identified to be food plants in the Pangani Basin. These are source of fruits, vegetables, tubers or other types of food. Most of the plant species in this category are terrestrial. Note that some of the names are given in vernacular language pending their identification.

5.2 Plants used as construction material

Most of the plants identified to be used for construction are wetland species though terrestrial plants also used for construction. The plants identified as source of construction material include *Phragmites* spp, *Typha capensis*, *Cyperus papyrus, Makuruwila, Hyphaene* spp (Mikoche), *Euphorbia sp (Minyaa/ Miaa)., Phoenix reclinata* (Kindu) *and Cocos nucifera (minazi)and Milicia excelsa* (Mvule) *Deinbolia kilimandscharica* var. *kilimandscharica (Appendix 1).* Further most of the terrestrial plants identified in the different zones of the basin may be used to produce construction material of one kind or another. *Cyperus papyrus* and *Hyphaene* are widely used in production of roofing material for houses, *Cocos nucifera, Milicia excelsa* (Mvule) and *Deinbolia kilimandscharica* var. *kilimandscharica* are used to produce timber and other construction material apart from Cocos being used as food. All mangrove species are good for poles that are locally and internationally used for various types of construction including boat making. *Euphorbia sp (Minyaa/Miaa)* are used in the construction of live livestock fences and live fences around homesteads and farm boundaries. All the mangrove species (A*vicenia marina, Bruguira gymnorrhza, Herritiera littoralis, Lumnitzera racemosa, Rhizophora mucronata, Sonneratia alba, Xylocarpus granatum and Ceriops tagal)* are good sources of construction material specifically poles.

Table 12 Plant Species identified to be a source of food in the Pangani River Basin

SN	Species Name		In Water	Wet bank	Dry bank
	Scientific	Vernacular			
1	*Syzygium guineense*	Mshihwi	-		√
2	*Syzygium cordatum*	Mzambarau	-		√
3	*Psidium guajava*	Mpera	-		√
4	Ficus sycomorus	Mkuyu	-	√	
5	Solanum sp.	Mnavu	-		
6	*Amaranthus spinosa*	Mbuluja	-		√
7	Sorindeia madagascariensis	kungwina/mkunguma	-		√
8	*Colocasia* sp	Magimbi	-		√
9	*Tamarindus indica*	Mkwaju	-		√
10	*Hyphaene* sp.	Mikoche/Mkochwe	-	√	
11	Zanthoxylum chalibeum	Msala/Msele	-	√	√
12	*Cardamine trichocarpa*	Msegeyu	-		√
13	*Synsepalum* sp	Msambia/Sambia	-		√
14	Rubus apetalus	Mtula/Mtelia	-		√
15	*Carica papaya*	Mpapai	-		√
16	*Eleis guineense*	Kindu	-		√
17	*Cocos nucifera*	Minazi	-	√	√
18	-	Mavungo	-		√
19	-	Mbondela	-		√
20	-	Horojo	-		√
21	-	Maungoungo	-		√
22	-	*Mgagani*	-		√
23	-	Bwebwe	-		√
24	-	Matuberi	-		√
25	-	Mchunga	-		√
26	-	Mtorilo	-		√
27	-	Makoma Kunazi	-		√
28	-	Sangale	-		√
29	-	Zinge	-		√
30	-	Tarata	-		√
31	-	Matufaa	-		√
32	-	Mtonga	-		√
33	-	Mgaa	-		√

5.3 Plants used for medicinal purposes

A number of plants are known to have medicinal value in the Pangani basin. There are about 30 plant species in the riparian zone that are identifiable as having medicinal qualities and are used by the local communities for medicinal purposes.

Table 13 Plant species used for medicinal purposes in the Pangani River basin

SN	Species Name	
	Botanical	**Vernacular**
1	*Triumfetta cordifolia* var. *tomentosa*	Msosokwe
2	*Deinbolia kilimandscharica* var. *kilimandscharica*	Bwakabwaka
3	*Englerophytum natalense*	Mdudu
4	*Ricinus communis*	Mnyonyo
5	Ximenia caffra	Mtundutwa
6	*Phoenix reclinata*	Kindu
7	*Salvadora persica*	
8	*Solanum incanum*	Ndulele
9	*Milicia excelsa*	Mvule
10	*Ficus sp*	Mkuyu
11		Mbwawa
12		Mtango
13		Mzera
14		Kilemela kuka
15		Chatendee
16		Ziya
17		Makoka
18		Mswaki
19		Usigisi
20		Kongo
21		Mshasha
22		Mkuvukuvu
23		Mtula
24		Mhunga
25		Kivumbasi
26		Mdaha
27		Rumbizi
28		Mvugunya
29		Mjarato
30		Mayungingi

6.0 SPECIES RESPONSE TO FLOW

6.1 Species attributes linked to flow

Different species respond differently to different environmental factors. One of the environmental factors in the Pangani system is flow which varies seasonally. The choice of species as an indicators of flow regimes was based three criteria; the position of the species in the different longitudinal zones (upstream-downstream distribution) on the river systems, lateral distribution of the species (aquatic, wet bank or dry bank) and where possible ecological and socio-economic significance of respective species. Further more for each longitudinal zone species that represent different growth forms (trees, herbs and shrubs) occurring in each lateral zone (aquatic, wet bank and dry bank) were used to indicate possible responses of each growth form to different flow regimes (Table 14).

Such variations will likely induce different characteristics on plants that inhabit the riparian zone as a response and adaptations. The species attributes linked to flow for selected plant species in different ecozones of the Pangani basin are shown in Table 15.

Table 14 Representative Species as Indicators of Response to Flow Regimes in the Pangani River Basin

Longitudinal Zone	Species	Growth Form	Lateral Distribution	Ecological/Socio-economic Importance					
				1	2	3	4	5	6
Mountain Stream	*Albizia schimperana*	Tree	Dry bank			√			
	Ficus capreifolia	Tree	Wet bank				√		
	Tithonia diversifolia	Herb	Dry bank					√	√
	Drymaria cordata	Herb	Wet bank			√	√		
	Pavetta stenocephala	Shrub	Dry bank						
	Vernonia hildebrandtii	Shrub	Wet bank				√		
Upper Foothill	*Albizia glaberrima*	Tree	Dry bank			√			
	Acacia xanthophloea	Tree	Wet bank				√		
	Abutilon mauritianus	Herb	Dry bank						
	Typha capensis	Herb	Aquatic/Wet bank			√	√		
	Ricnus comunis	Shrub	Dry bank		√				
	Suaeda monoica	Shrub	Aquatic/wet bank				√		
Lower Foothill	*Sclerocarya birrea ssp caffra*	Tree	Dry bank	√		√			
	Ficus sur	Tree	Wet bank				√		
	Cyperus articulatus	Herb	Wet bank				√	√	√
	Trichilia emetica	Tree	Dry bank		√	√			
	Kylinger elata	Shrub	Wet bank				√		
Rejuvenated Bedrock /Mature Lowland River	*Acacia polyacantha*	Tree	Dry bank			√			√
	Baringtonia racemosa	Tree	Wet bank		√				
	Phoenix reclinata	Shrub	Dry Bank		√		√		
	Cyperus exaltatus	Herb	Wet bank				√	√	√
Estuary	*Cocos nucifera*	Tree	Dry bank	√			√		
	Rhizophora mucronata	Tree	Wet bank				√	√	
	Xylocarpus granatum	Tree	Wet bank				√	√	

1 Food
2 Medicine
3 Construction
4 Indicator Species
5 Keystone Species
6 Ecosystem Engineer

Table 15 Species attributes linked to flow in the Pangani River basin (Key: Flow Variable 1=median discharge, flow duration and number of flood peaks above 1:0.5, Flow Variable 2=minimum 7- day flow)

Site	Representative Species	Flow Variable	Response to Flow Regimes
Mountain Stream Zone	*Albizia schimperana*	1	• This is a deep rooted terrestrial tree species which is capable of obtaining underground water during dry season. • Increasing median flow the trees grow better. • If the median flow decreases the trees can still survive though its growth may decrease. • Increasing the duration of flow may kill the trees • If the frequency of flood peaks (small floods) increases the trees may not be affected.
		2	• These species can still survive at 7 - days min. Q.
	Ficus capreifolia	1	• It is a catchment tree species of the wet bank. • During dry season (when median flow decreases), Ficus species can obtain underground water using its deep roots. • Under flooded environment, the species can still survive although the performance will decrease
		2	• If the minimum 7–day flow decreases the species can still survive as it can use its deep roots to extract water from underground sources.
	Tithonia diversifolia	1	• A dry bank herb • Increase in median and duration flow will increase the growth of the plant as more water will be available • Increase in flood peaks may not affect the plant
		2	• The species growth will decrease with decrease in the dry season minimum 7-day flow. On the other hand increase in the minimum 7-day flow increases the growth of the plant
	Drymaria cordata	1	• This is a wet bank species • Decrease in the median flow increases the growth of the plant • Increase in the flow duration and flood peaks during the long rains will decrease the growth of the species
		2	• Decrease in the dry season 7-day minimum flow will decrease the growth of the plant

Site	Representative Species	Flow Variable	Response to Flow Regimes
Mountain Stream Zone	*Pavetta stenocephala*	1	• A dry bank shrub • Decreasing the median flow, duration of flow and flood peaks will lead into decrease in growth of the plant as water availability becomes less for dry bank species
		2	• Decrease in the 7-day minimum flow during the dry season kills the plants and reduce their abundance
	Vernonia hildebrandtii	1	• A wet bank shrub • Decrease in median flow, duration of flow and small flood peaks will reduce the growth of the plants
		2	• Decrease in the 7-day minimum flow during the dry season will likely kill the plants
Upper Foothill Zone	*Albizia glaberrima*	1	• This is a deep rooted dry bank tree species which is capable of obtaining underground water during dry season. • Increasing median flow the trees grow better. • If the median flow decreases the trees can still survive though its growth may decrease. • Increasing the duration of flow may kill the trees • If the frequency of flood peaks (small floods) increases the trees may not be affected.
		2	• These species can still survive at 7 - days min. Q.
	Acacia xanthophloea	1	• A wet bank tree species • The plants grows better if median flow is increased • If median flow is decreased, the growth will also decrease
		2	• If the minimum 7 – day flow decreases the plants may die
	Abution mauritianum	1	• A dry bank herb • Increasing the median flow will increase the growth of the species thus its abundance. • If median flow decreases the growth will not be affected.
		2	• If the minimum 7–day flow is decreased the plant will start to dry.
	Typha capensis	1	• A wet bank herb • This species is a water lover and will survive well under high water levels. The species cannot survive if the median decreases. • Flooding will increase the growth and survival of the species. • Constant median flow won't change the growth of the species.
		2	• Decrease in the minimum 7 – day flow will kill the species

Site	Representative Species	Flow Variable	Response to Flow Regimes
Upper Foothill Zone	*Ricinus communinis*	1	• A dry bank shrub • This is a terrestrial shallow rooted shrub hence a dry bank species. • It is adapted to dry conditions and can survive well at median discharge in all seasons and prolonged flow duration during the long rains.
		2	• The species can still survive minimum 7 day Q during the short rains • It may die during the dry seasons under decreasing minimum 7-day flow
	Suaeda monoica	1	• A wet bank shrub • Decrease in the median flow and duration of flow may kill the plant • Increase in small flood increases the growth of the plant
		2	• Decrease in the 7-day minimum flow during the dry and short rain seasons may kill the plant
	Barringtonia racemosa	1	• Under flooding conditions the trees may die. • The trees will survive if media flow decrease as they have deep roots that can extract underground water
		2	• The trees will still survive at minimum 7-day flow,
			•
			•
Lower Foothill Zone	*Sclerocaria birrea ssp caffra*	1	• A dry bank tree • A widespread terrestrial tree species adapted to semi-arid conditions. • Can grow and survives well under median discharge during all seasons. • It may not withstand long duration of discharge and numerous flood peaks during the rain season.
		2	• Being a tree with deep roots and adapted to dry conditions it can still survive well under minimum 7 day flow in the dry season and short rains.
	Ficus sur	1	• This is a dry bank deep rooted species. It will survive well under median discharges during dry, short and long rain seasons.
		2	• Because it has deep roots that can extract water from deep soil profiles it will not be affected by minimum 7 day flows though flooding may reduce its growth.

Site	Representative Species	Flow Variable	Response to Flow Regimes
Lower Foothill Zone	*Cyperus articulatus*	1	• A wet bank herb • This is a shallow rooted aquatic species which require enough moisture for its growth. • Decrease in the median flow will reduce the abundance of the species and may die • Increase in the frequency of small flood peaks may reduce the growth of the species
		2	• Decrease in the minimum 7 – day flow during the dry season will kill the species
	Trichilia emetica	1	• A dry bank terrestrial tree species • It has long roots that can extract water from deep underground sources during dry season. • An increase in median flow results in better growth • A decrease in the median flow the species can still survive since it can use its deep roots to extract water from underground sources • Flooding under prolonged flow durations will kill the species as it is not adapted to flooded conditions
		2	• If the minimum 7 – day flow decreases during the dry season the species can still survive as it can use its deep roots to extract water from underground sources
	Kylinger ellata	1	• A wet bank shrub • Growing well under high moisture levels. • It can survive well under increased medium flow, flow duration and flood peaks. • The species will die with decreasing median flow.
		2	• The species cannot survive under persistent low water levels and thus its growth will greatly slow down or die with decreasing minimum 7 - day flow during the dry season and short rains.
Rejuvenating River/Mature Lowland River	*Acacia polyacantha*	1	• A dry bank tree • Can survive better under adequate moisture conditions. • Grows well at median discharge and long flow durations during the dry, short and long rains
		2	• The species being a tree up to 25 m height have deep roots that can extract moisture from underground sources • Can still grow well at minimum 7 day flow during all seasons

Site	Representative Species	Flow Variable	Response to Flow Regimes
	Baringtonia racemosa	1	• A wet bank tree • Can survive better under increasing median flow conditions • The tree can still survive under long flow durations and flood peaks
		2	• Decrease in the minimum 7 – day flow during the dry season will likely kill the tree in the long run
	Phoenix reclinata	1	• A wet bank species usually grows in alluvial soils near stream banks with permanent access to ground water. • Can access deep ground water. • Can grow well under median discharge in the dry, short rain and long rain seasons also under long duration flow.
		2	• Being a water lover and surviving where it can access enough moisture its growth may decrease under minimum 7 - day flow conditions during the dry season
	Cyperus rotundus	1	• A wet bank herb • It is adapted to a wide range of moisture conditions. • It can survive well at median flow, long duration of flow and different small flood peaks during the dry, short and long rain seasons
		2	• It can survive well under minimum 7 day flow during the rain season • Its growth may somehow be decreased under decreasing minimum 7 day flow during the dry season
Estuary Zone	*Cocos nucifera*	1	• Widespread coastal species found growing on elevated grounds around the estuary. • Not adapted to high water table or high flooding. • Both median discharge and frequency of flood peaks will not affect the growth of the species in all seasons • On the other hand increase in the duration of flow will decrease the abundance of the species
		2	• Decrease in the 7-day minimum flow will tend to reduce the growth of the specie during the dry season and short rains

Site	Representative Species	Flow Variable	Response to Flow Regimes
	Rhizophora mucronata	1	• Grows well on firm ground as well as in soft mud • Believed to be among the few species that can survive complete daily inundation. • Median discharge, duration of flow and frequency of flood peaks have no effect the abundance of the species in all seasons
		2	• Decrease in minimum 7–day flows in the dry season will reduce the growth and abundance of the species.
	Xylocarpus granatum	1	• Commonly occurs in the upper intertidal zone of mangrove forests • Mature trees are occasionally found at lower elevations. • Changes in median flows do not have effects on the species in all seasons • Changes in duration of flow and small flood peaks do not have any effect on the species
		2	• Decrease in the minimum 7-day flow especially during the dry season will likely reduce the growth of the species

6.2 Conceptual Models – Response Curves

The response curves below show how different representative species in the different ecozones of the Pangani River basin will respond to different flow regimes i.e. figures 5(a – i) for the mountain stream zone, figures 6(a – h) for the upper foothill zone, figures 7(a-i) for the lower foothill zone, figures 8(a-i) for the rejuvenated bedrock cascade zone, figures 9(a-i) for the mature lowland zone and figures 10(a-i) for the estuary.

For each zone the selected species represent the aquatic section, the wet bank section and the dry bank section of the river cross section assuming that they will respond differently given the different flow regimes.

The flow regimes considered here are median flow during the dry and short rain seasons which give the typical flows (cumecs) during the dry season and short rain season. The 7-day minimum flow variable (cumecs) during the dry season and the short rain seasons gives an indication of average flow over a 7-day period when flows are at a minimum during the dry season and short rain seasons.

On the other hand, duration of flow (days) indicate the duration of flows higher than the mean flow during the long rain season, while the median flow (cumecs) during the long rains represent the flows higher than the mean flow during the long rains giving a sense of typical high flows. The small flood peaks (m) during the long rains mean relative stage height of the largest flood peak during the long rains which gives a sense of the magnitude of high flows.

These curves were used as input into the preparation of the Pangani Flow Assessment Tool

6.2.1 Response Curves for Selected Plant Species in the Mountain Stream Zone Pangani River Basin

The representative species in this zone include *Albizia schimperana* (dry bank tree), *Ficus capreifolia* (wet bank tree), *Tithonia diversifolia* (dry bank herb) *Drymaria cordata* (wet bank hedb), *Pavetta stenocephala* (dry bank shrub) and *Vernonia hildebrandtii* (wet bank shrub). The response curves for the species are shown in figures 6(a-i). The **x** and **y** axes represent the present day conditions of flow and species abundance. The curves therefore show the response of species relative to its current abundance and current flow.

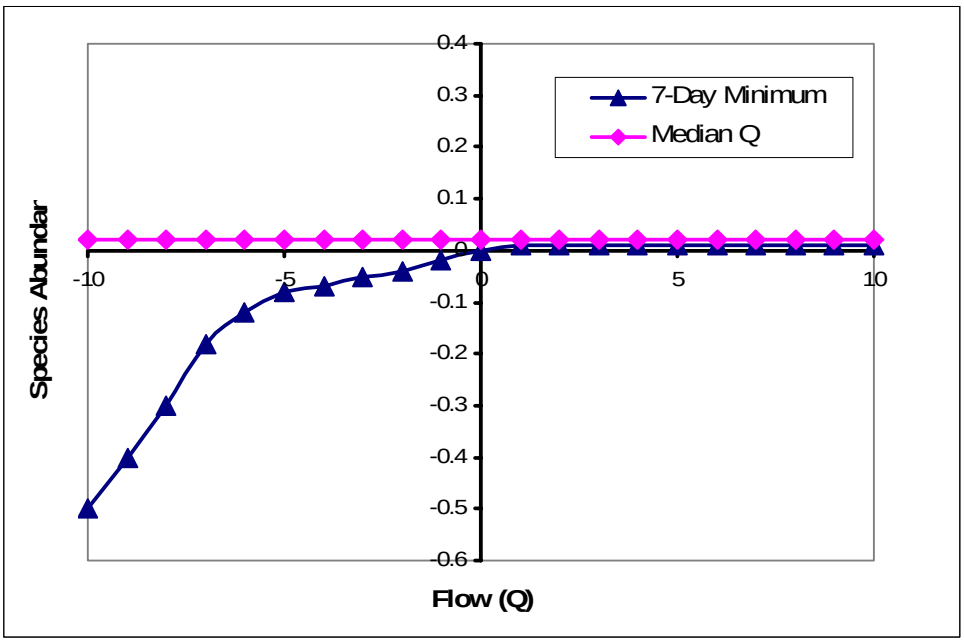

Figure 6(a) ***Albizia schimperana*** **(Dry Season 1 & 2)**

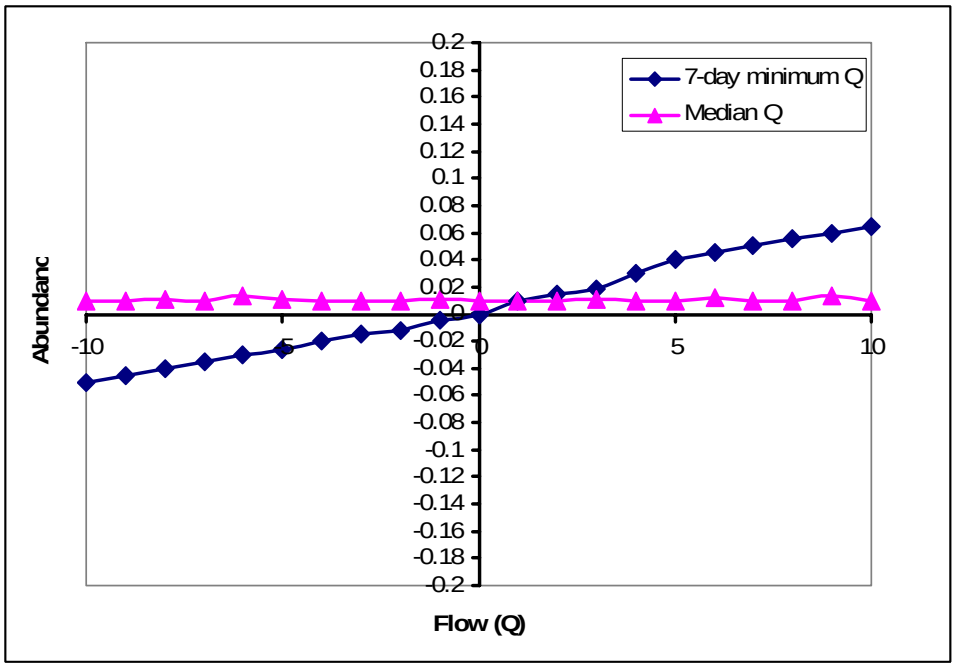

Figure 6(b) ***Albizia schimperana*** **(Short Rains)**

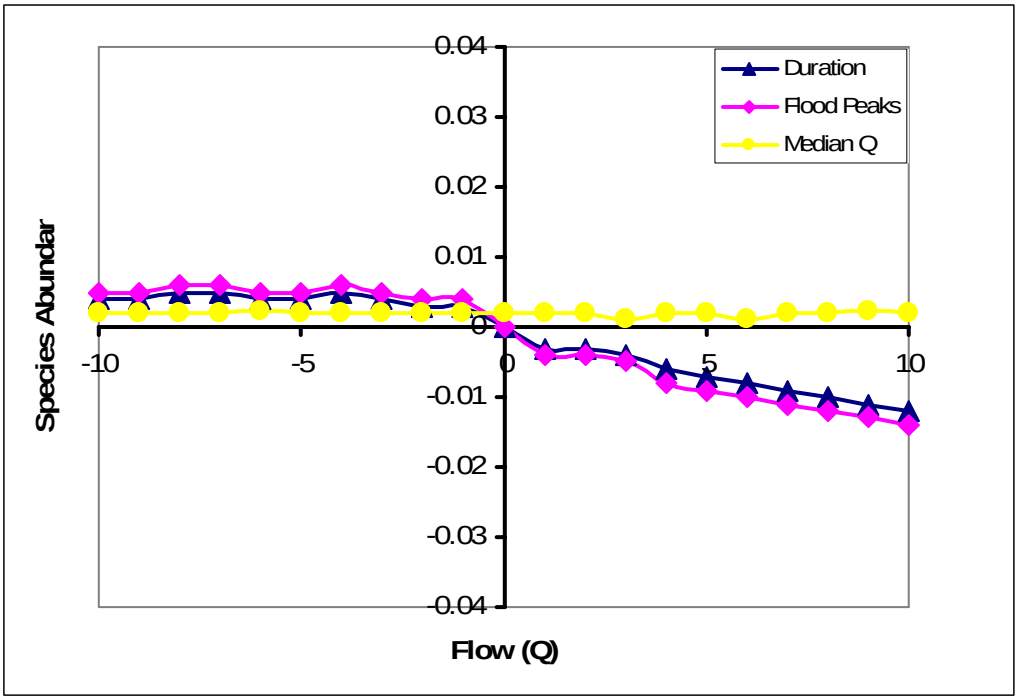

Figure 6(c) *Albizia schimperana* (Long Rains)

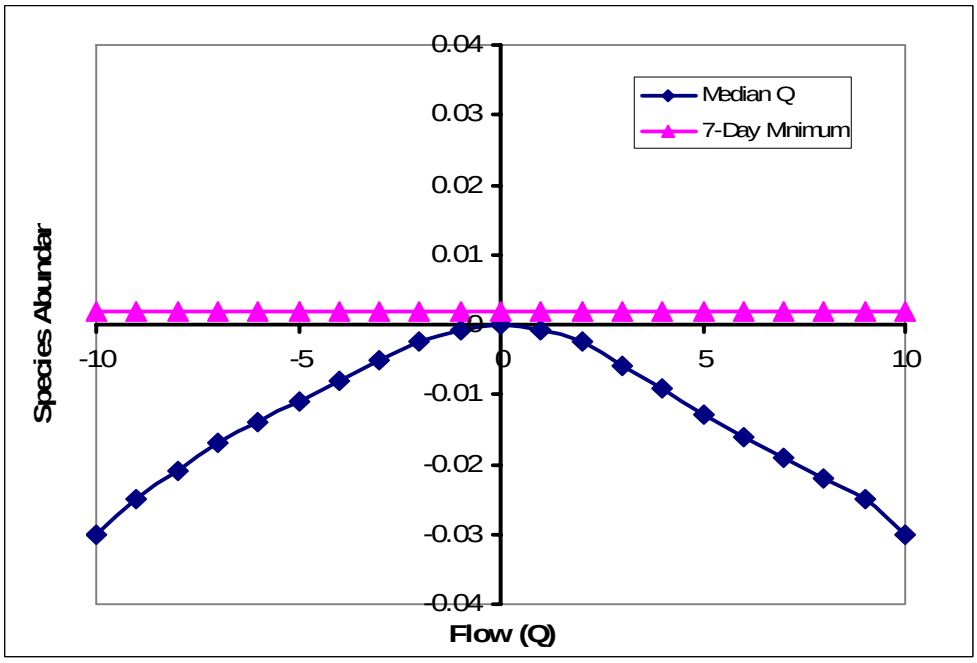

Figure 6(d) *Ficus capreifolia* (Dry Season 1 &2)

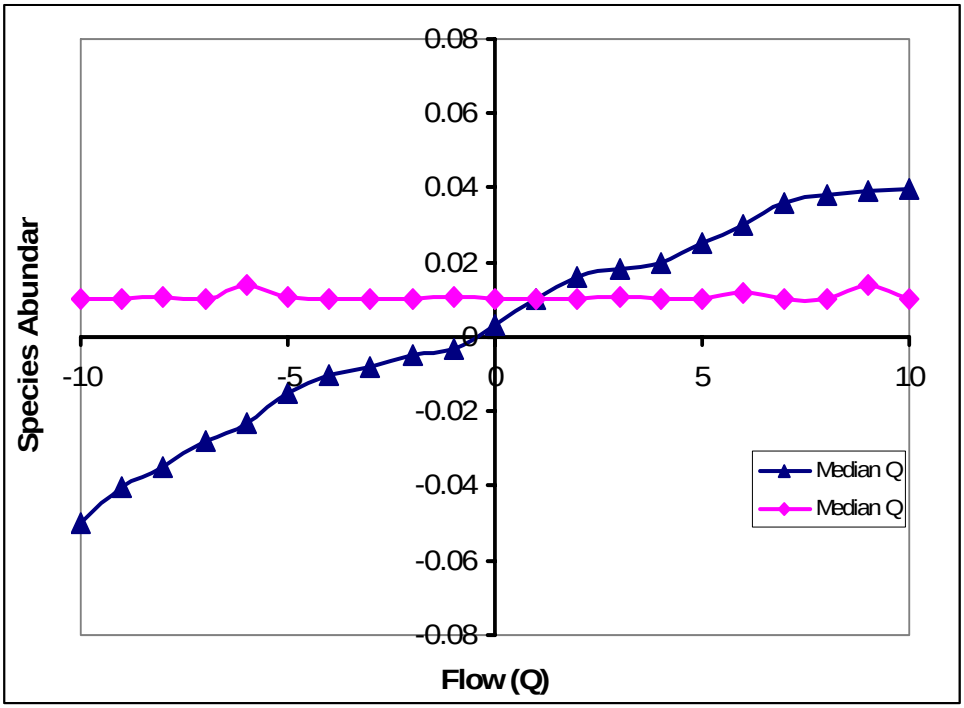

Figure 6(e) *Ficus capreifolia* (Short Rains)

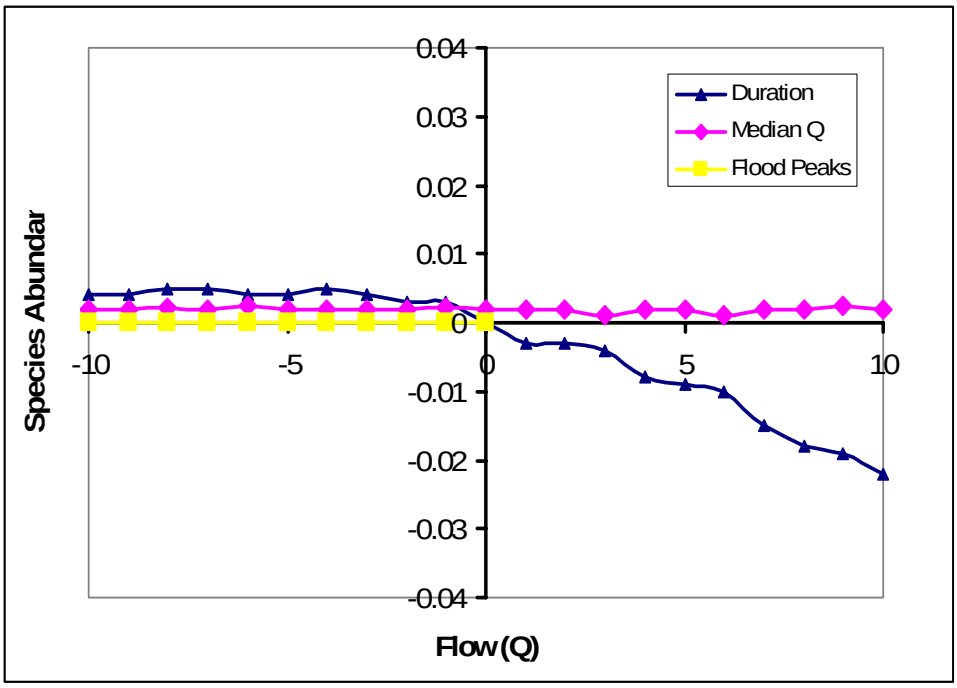

Figure 6(f) *Ficus capreifolia* (Long Rains)

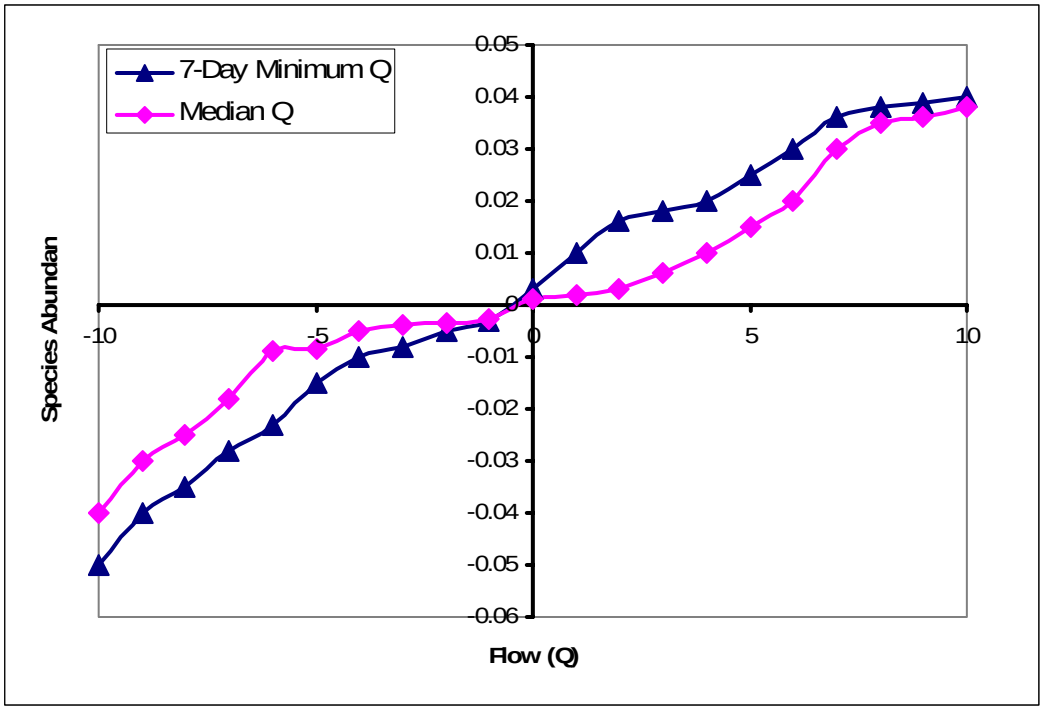

Figure 6(g) *Drymaria cordata* (Dry season 1& 2)

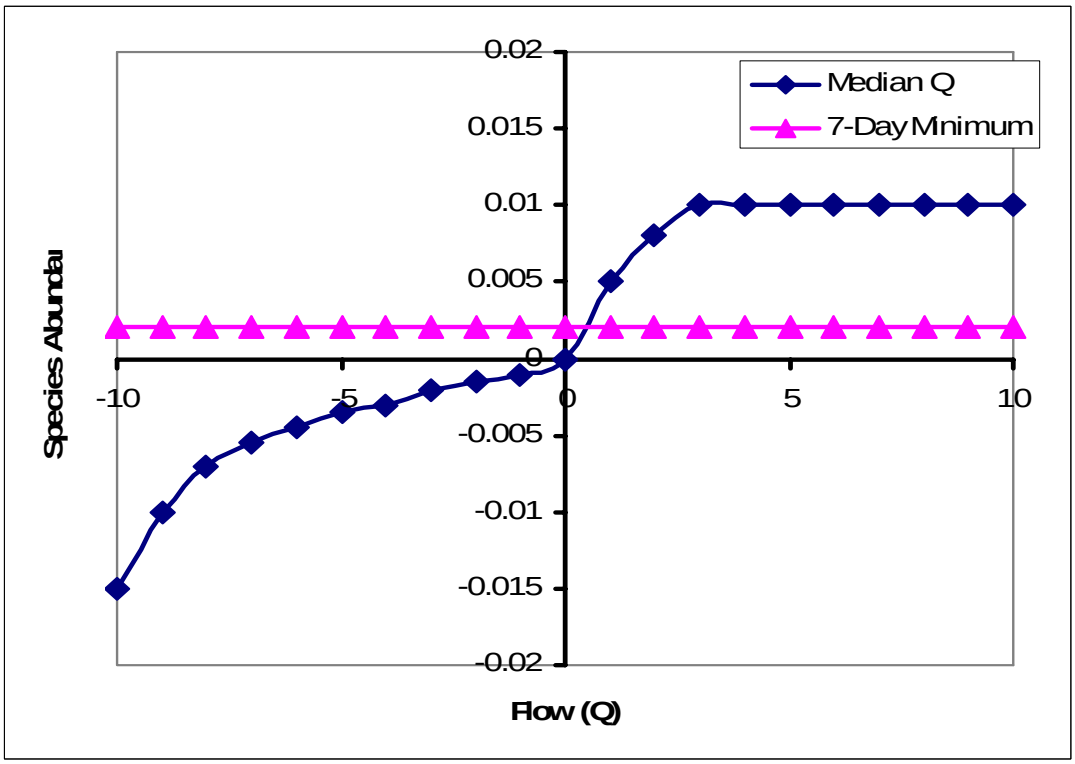

Figure 6(h) *Drymaria cordata* (Short Rains)

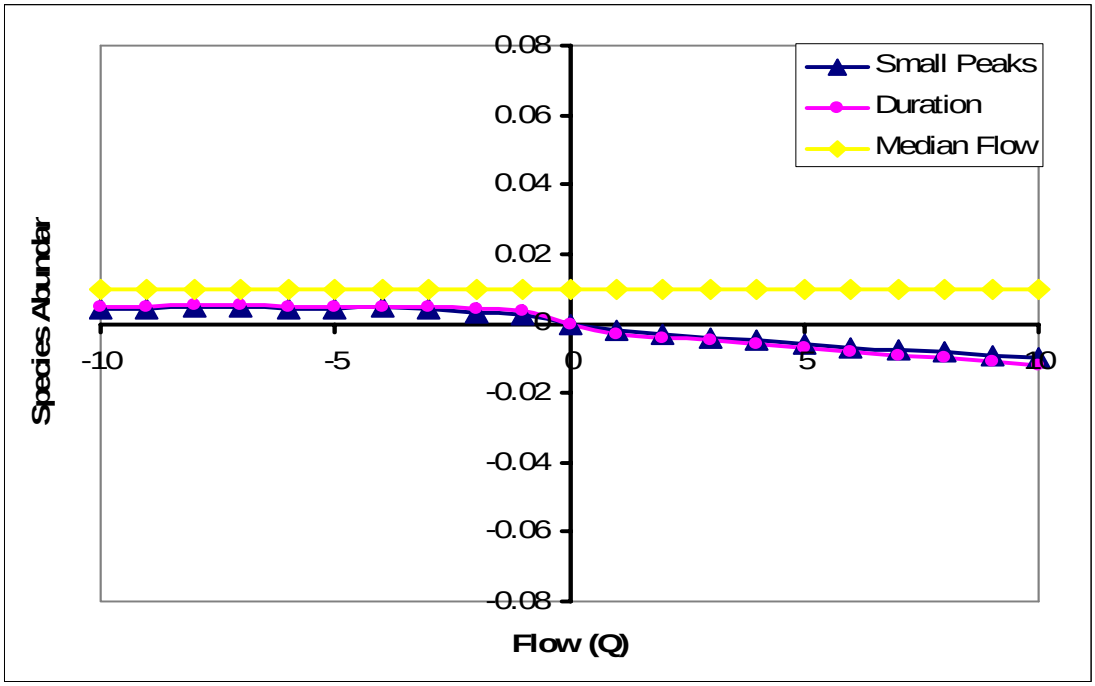

Figure 6(i) *Drymaria cordata* (Long Rains)

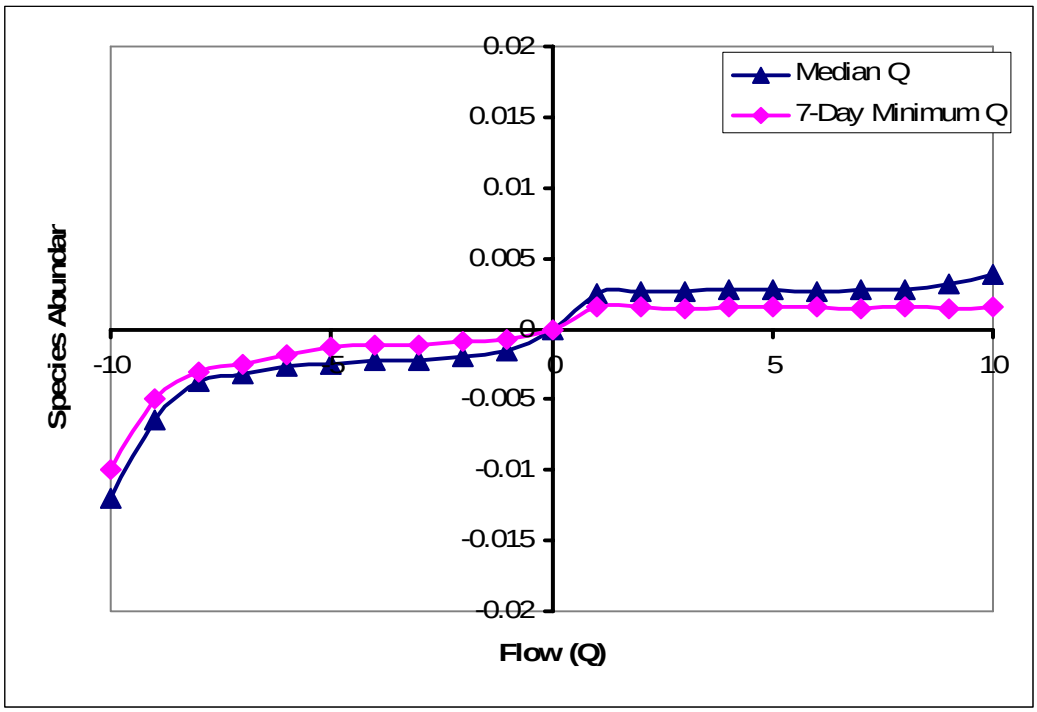

Figure 6(j) *Pavetta stenocephala* (Dry season 1 & 2)

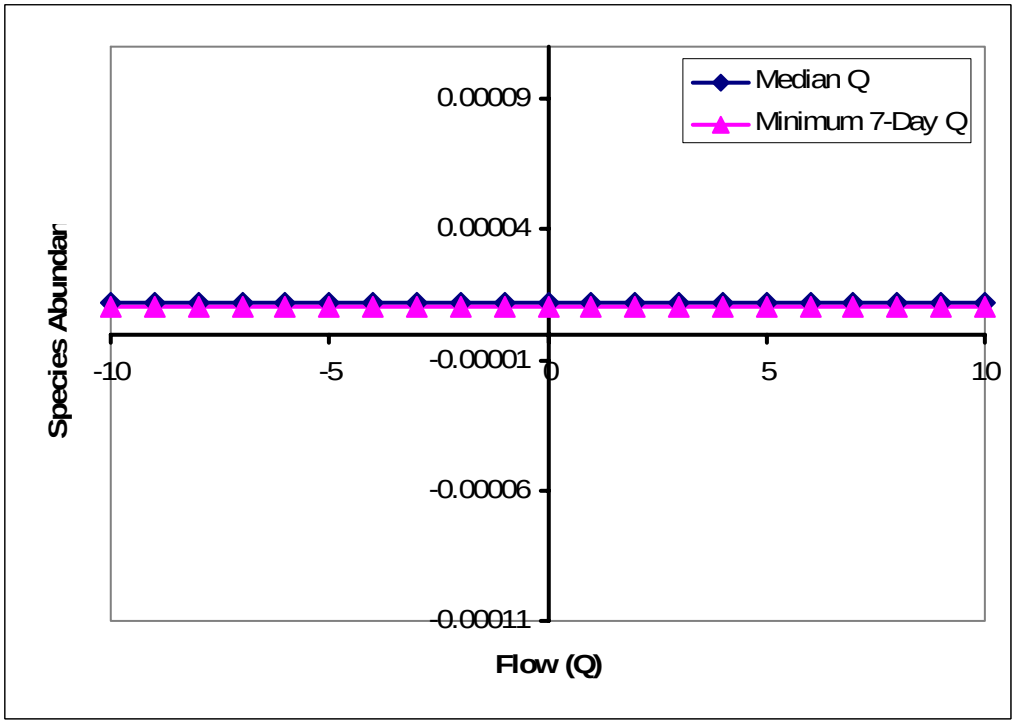

Figure 6 (k) *Pavetta stenocephala* (Short Rains)

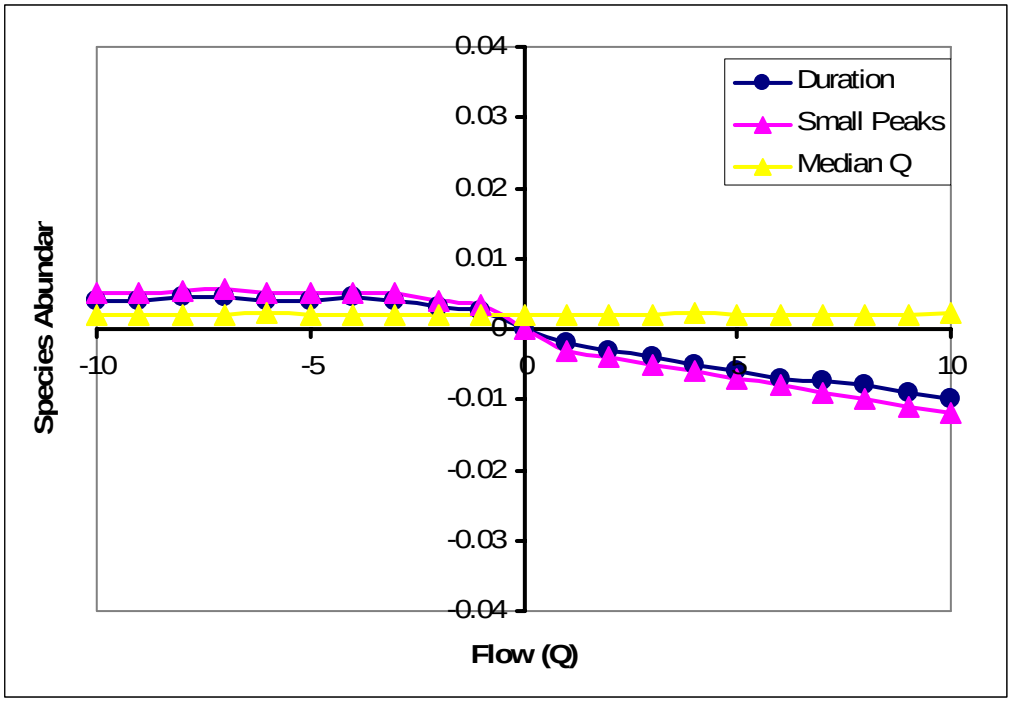

Figure 6(l) *Pavetta stenocephala* (Long Rains)

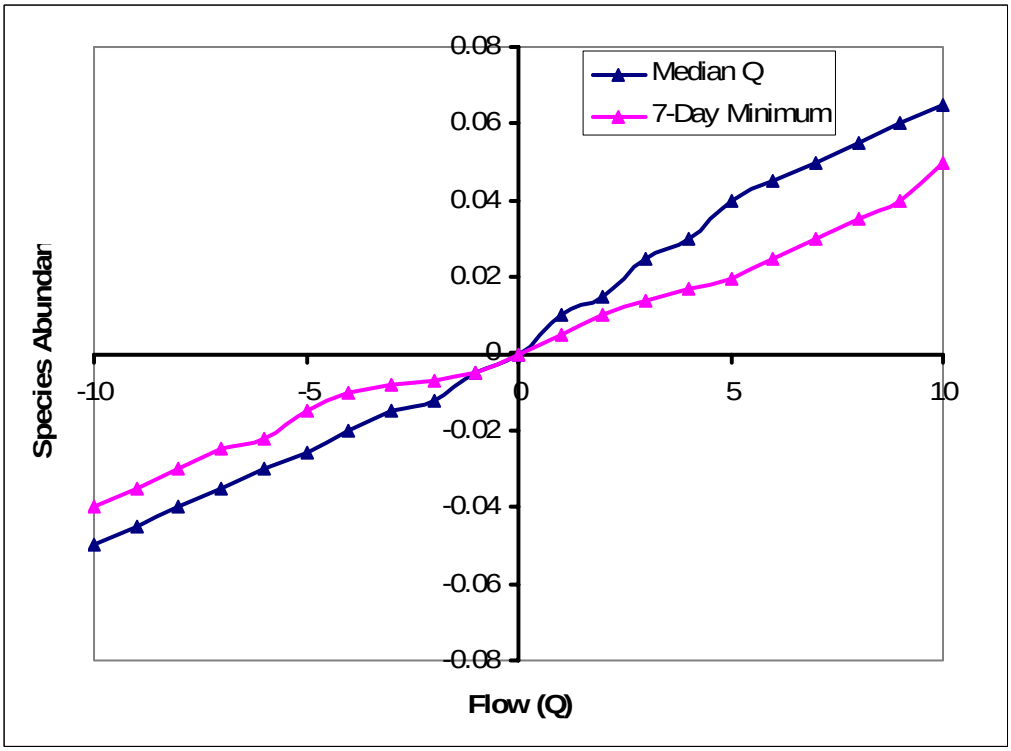

Figure 6(m) *Vernonia hildebrandtii* (Dry Season 1 &2)

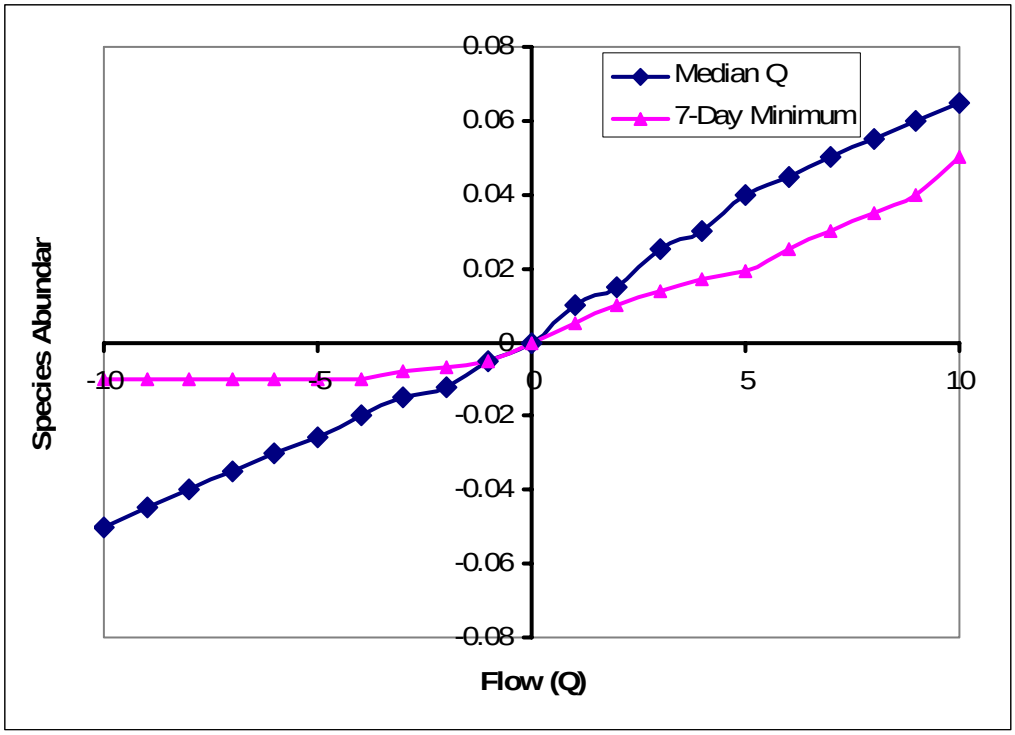

Figure 6(n) *Vernonia hildebrandtii* (Short Rains)

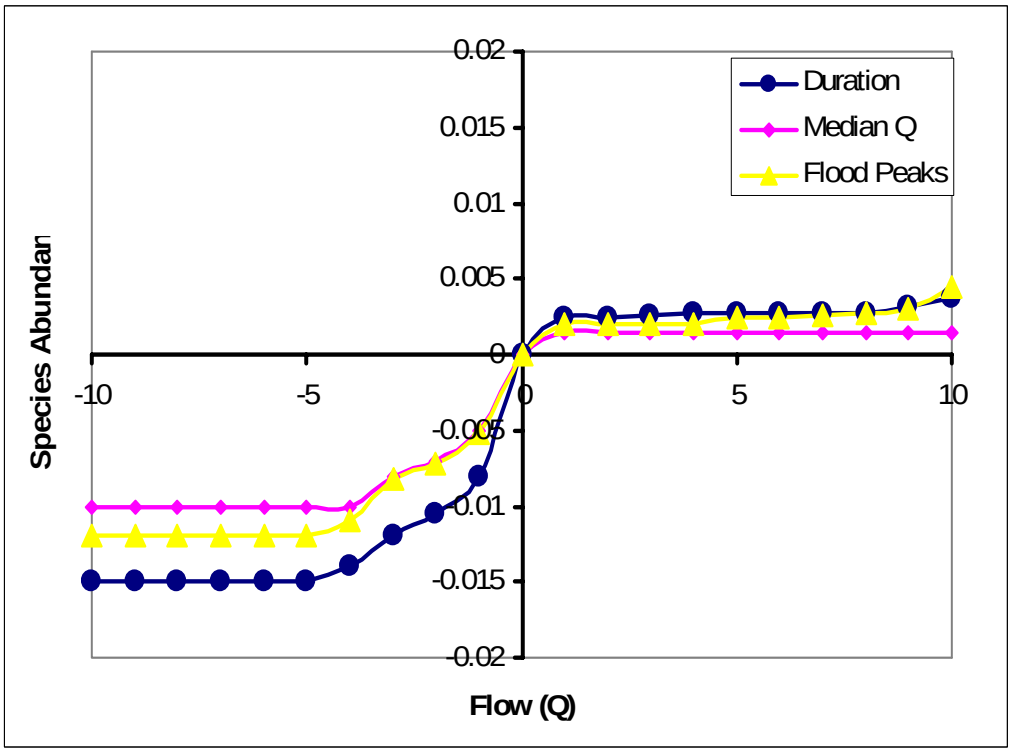

Figure 6(o) *Vernonia hildebrandtii* (Long Rains)

6.2.2 Response Curves for Selected Plant Species in the Upper Foothill Zone Pangani River Basin

The representative species in this zone include *Albizia glaberrima* (dry bank species), Acacia *xanthophloea* (wet bank species), *Abutilon mauritianus* (dry bank herb), *Typha capensis* (wet bank herb), *Ricinus comunis* (dry bank shrub) and *Suaeda monoica* (wet bank shrub). The response curves for the species are shown in figures 7(a-o). The **x** and **y** axes represent the present day conditions of flow and species abundance and therefore the curves show the response relative to the present day abundance and flow.

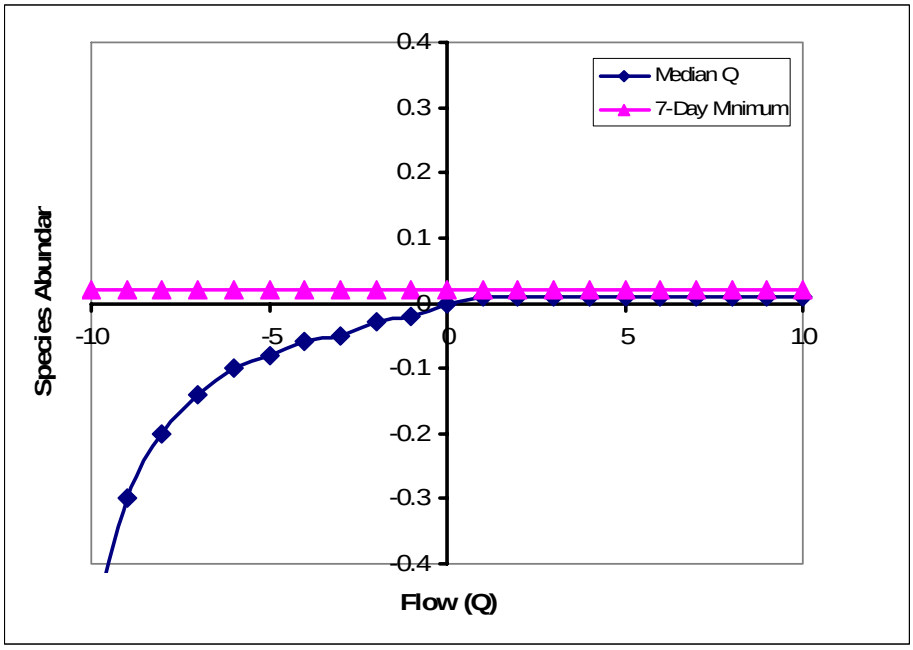

Figure 7(a) ***Albizia glaberrima*** **(Dry season 1 & 2)**

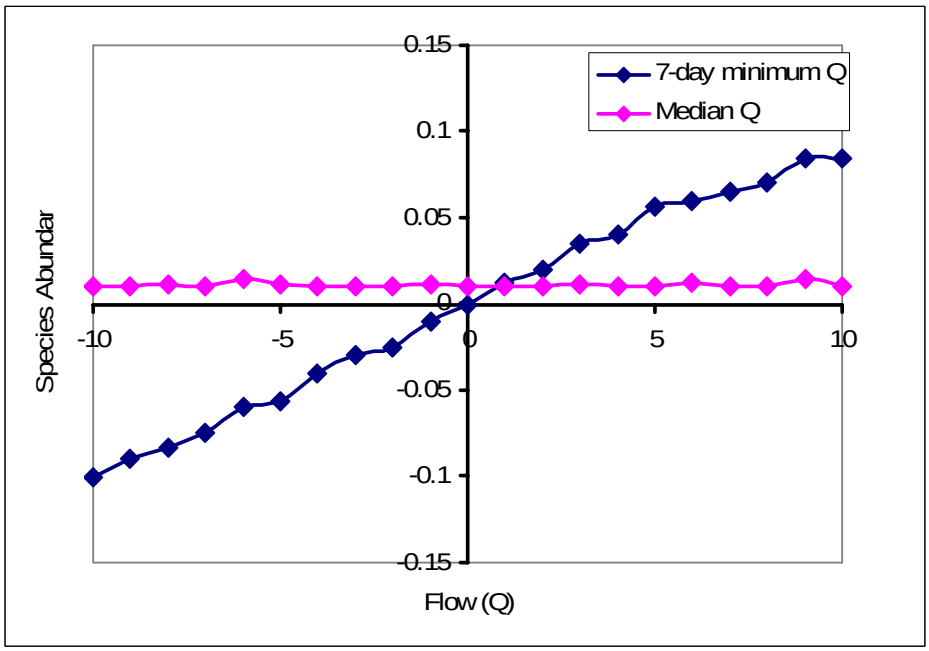

Figure 7(b) ***Albizia glaberrima*** **(Short Rains)**

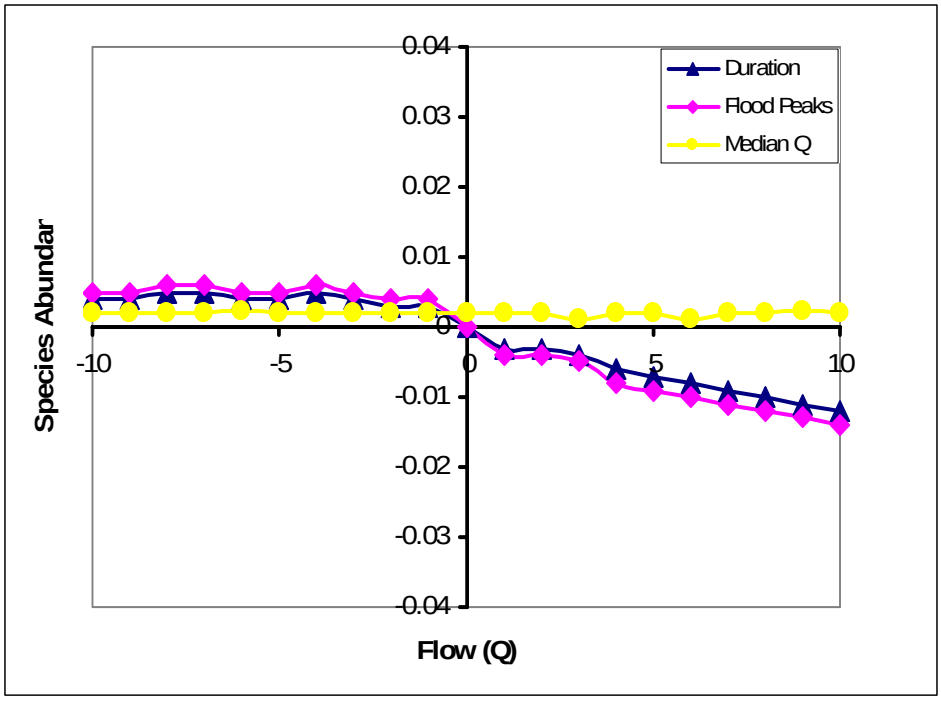

Figure 7(c) *Albizia glaberrima* (Long Rains)

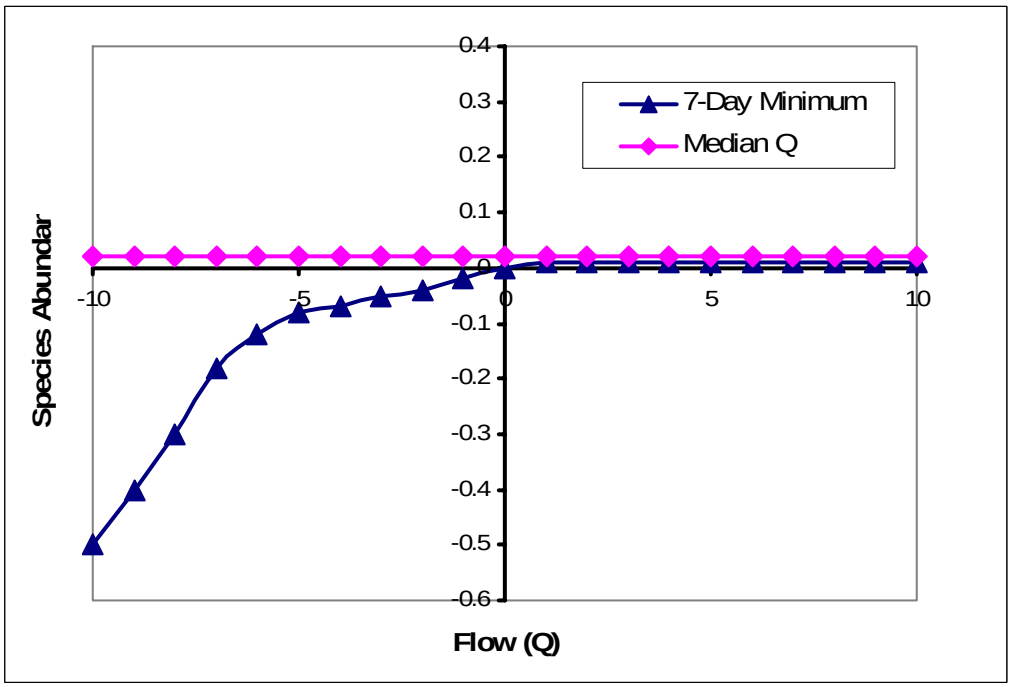

Figure 7(d) *Acacia xanthophloea* (Dry season 1 & 2)

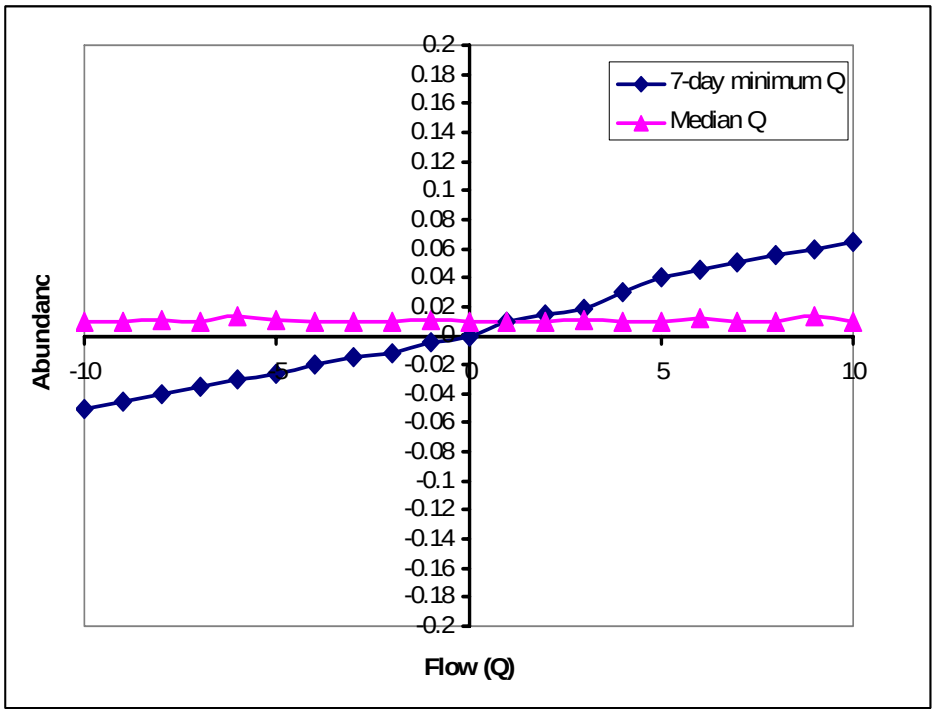

Figure 7(e) *Acacia xanthophloea* (Short rains)

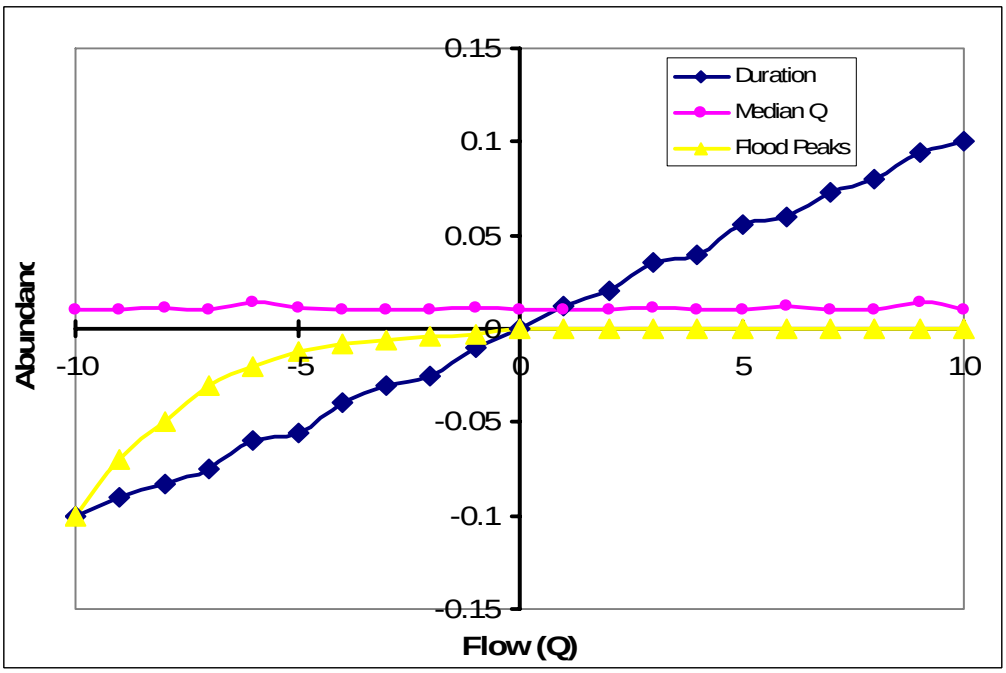

Figure 7(f) *Acacia xanthophloea* (Long rains)

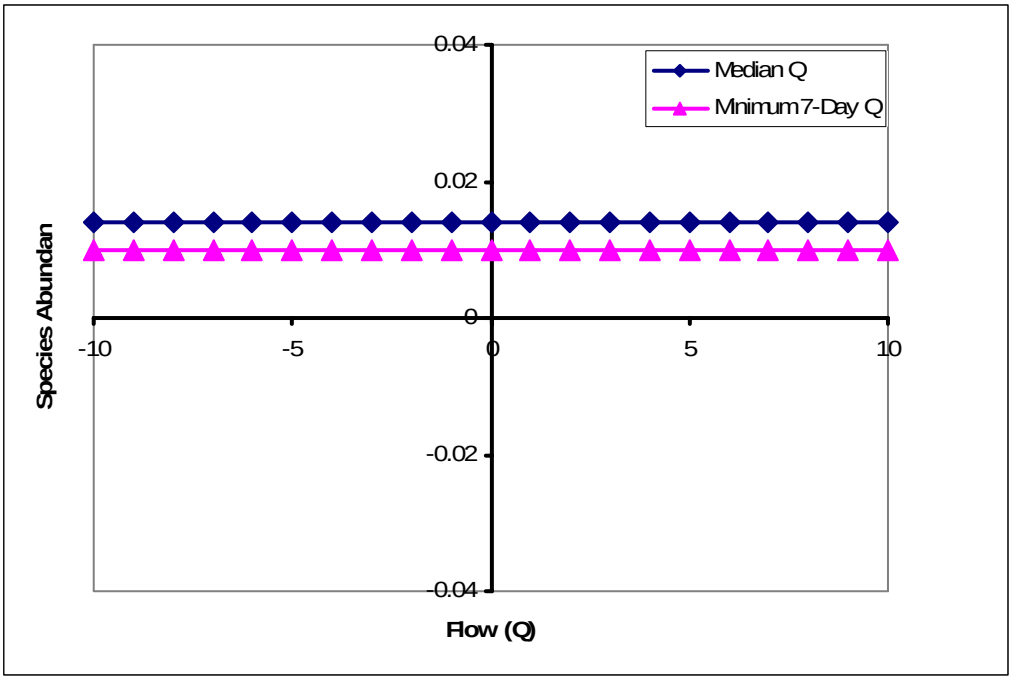

Figure 7(g) *Abutilon mauritianum* (Dry season 1 & 2)

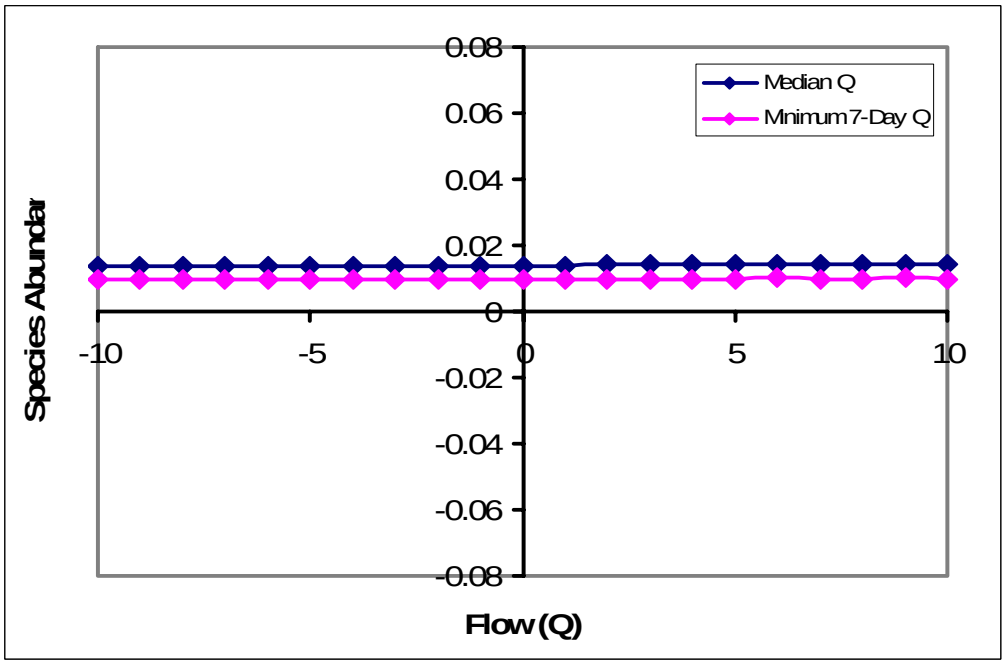

Figure 7(h) *Abutilon mauritianum* (Short Rains)

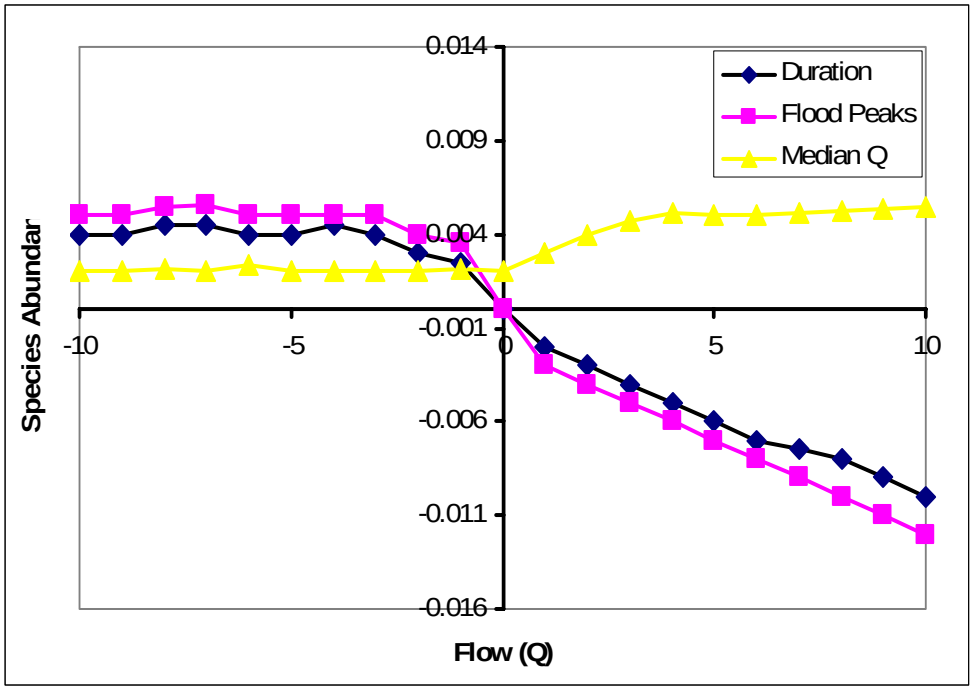

Figure 7(i) *Abutilon mauritianum* (Long Rains)

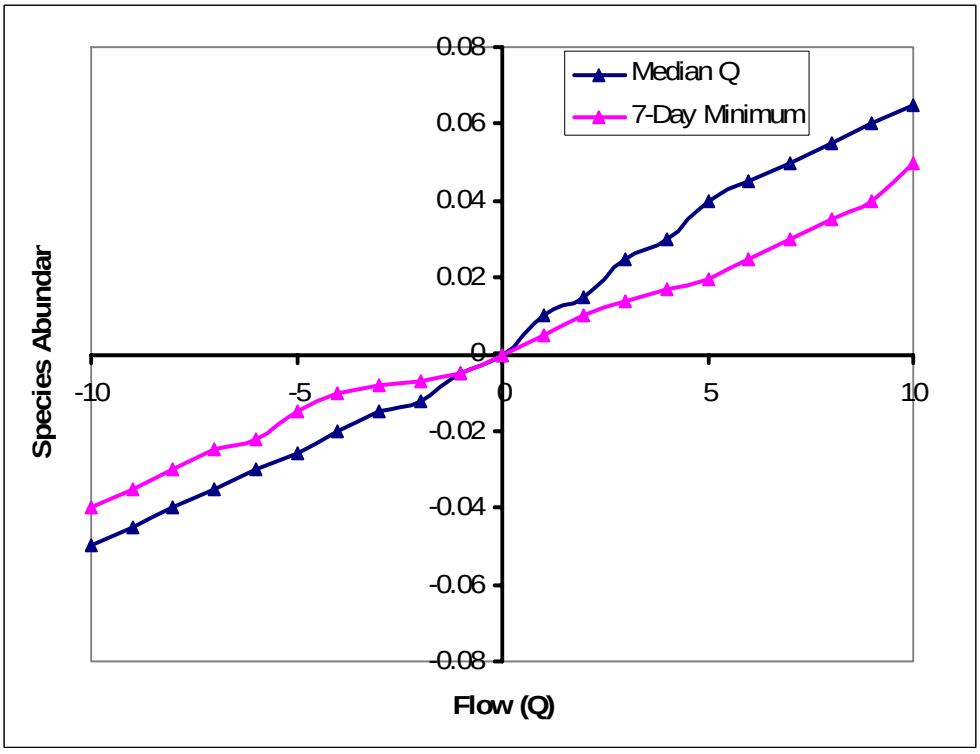

Figure 7(j) *Typha capensis* (Dry seasons 1 & 2)

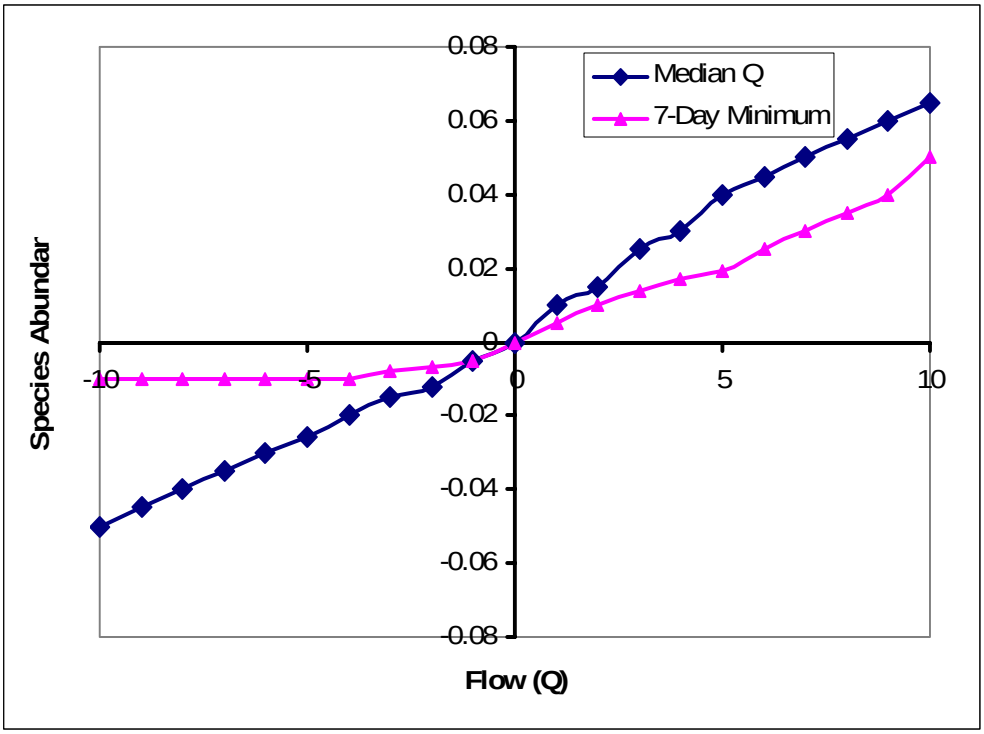

Figure 7(k) *Typha capensis* (Short Rains)

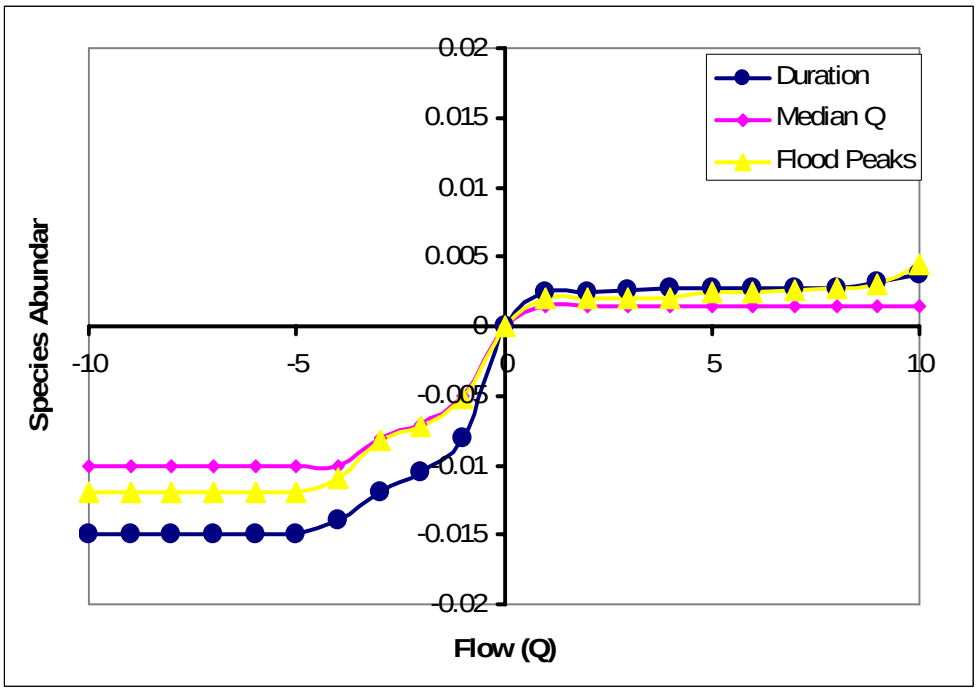

Figure 7(l) *Typha capensis* (Long Rains)

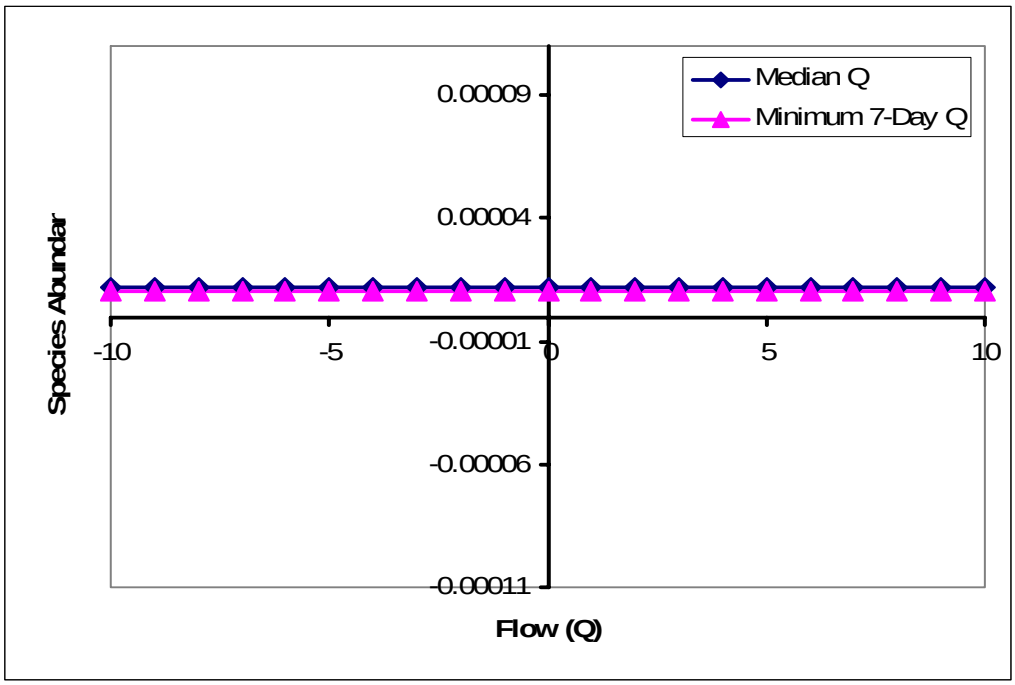

Figure 7(m) *Ricinus communis* (Dry seasons 1 & 2)

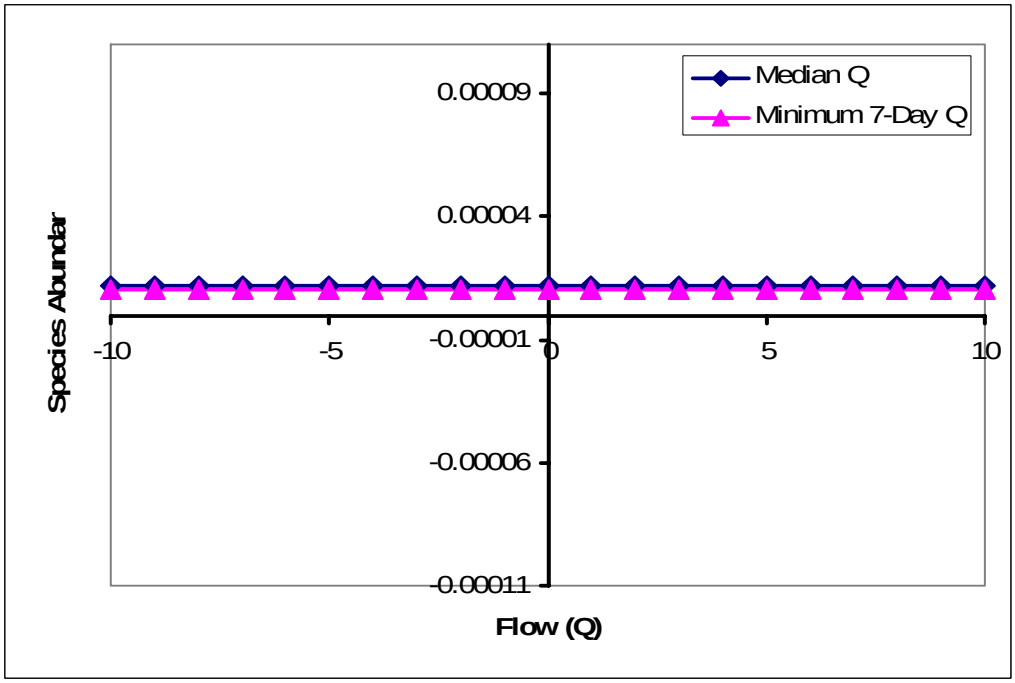

Figure 7(n) *Ricinus communis* (Short Rains)

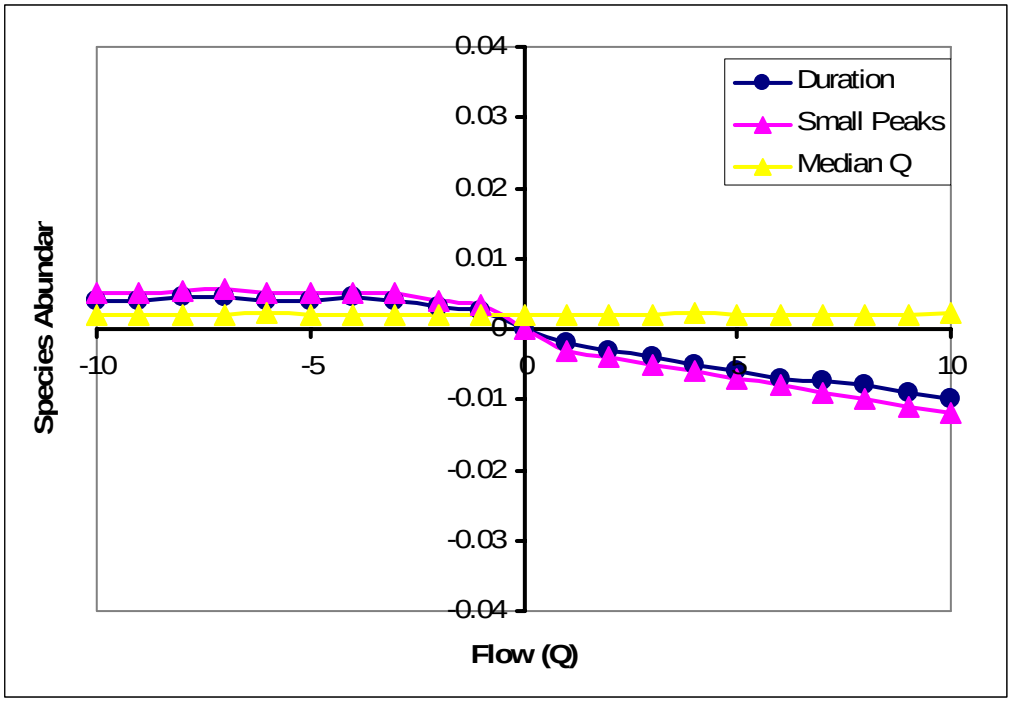

Figure 7(o) *Ricinus communis* (Long Rains)

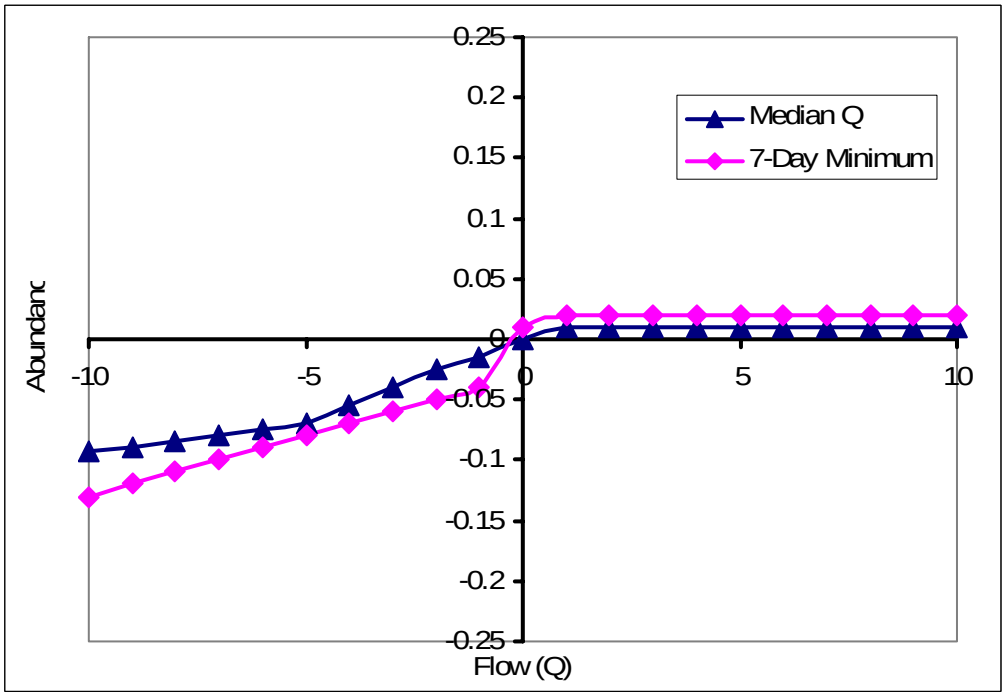

Figure 7(p) *Suaeda monoica* (Dry season 1&2 and Short Rains)

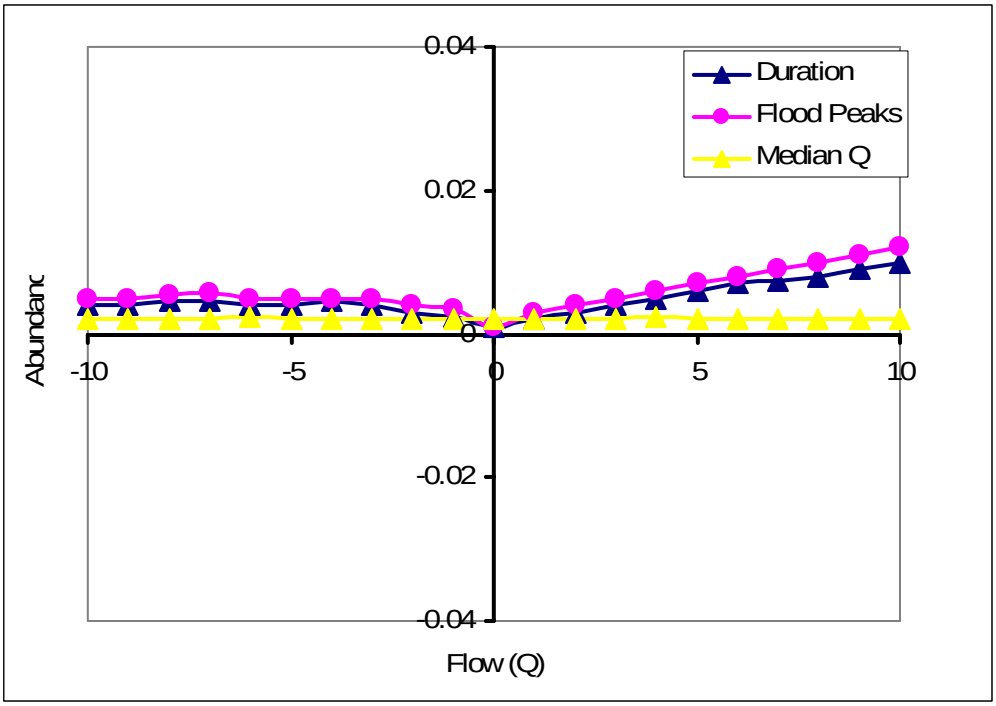

Figure 7(q) ***Suaeda monoica*** **(Long rains)**

6.2.3 Response Curves for Selected Species in the Lower Foothill Zone

The representative species in this zone include *Sclerocarya birrea ssp caffra* (dry bank tree), *Ficus sur* (wet bank tree), *Cyperus articulatus* (wet bank herb), *Trichilia emetica* (wet bank tree), *Kylinger elata* (wet bank shrub). The response curves for the species are shown in figures 8(a-i). The **x** and **y** axes represent the present day conditions of flow and species abundance.

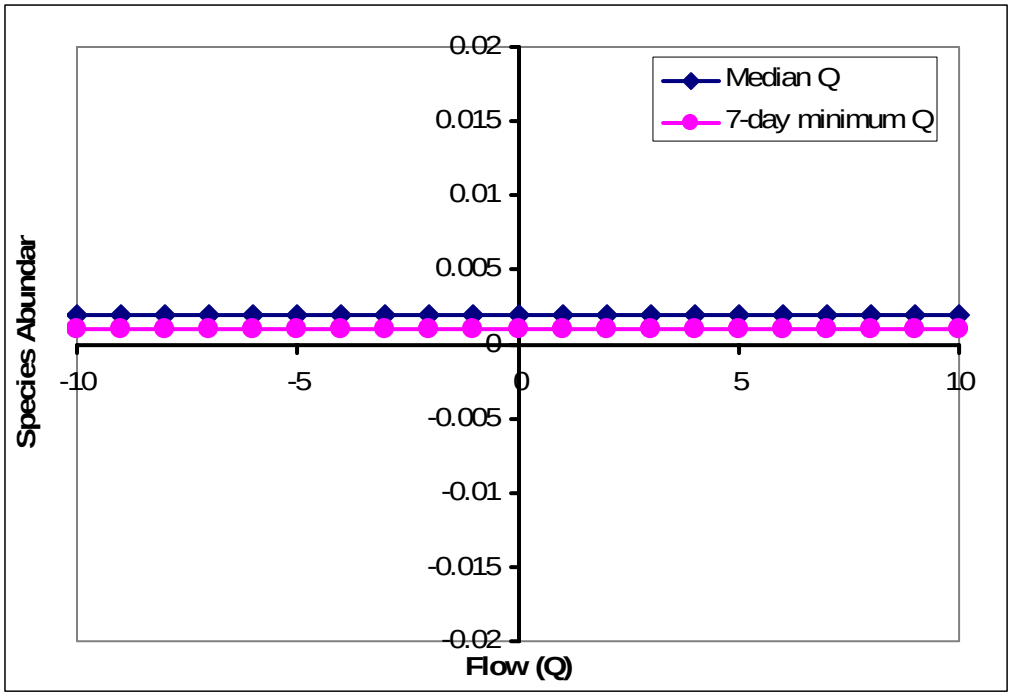

Figure 8(a) ***Sclerocarya birrea* ssp *caffra* (Dry seasons 1 & 2)**

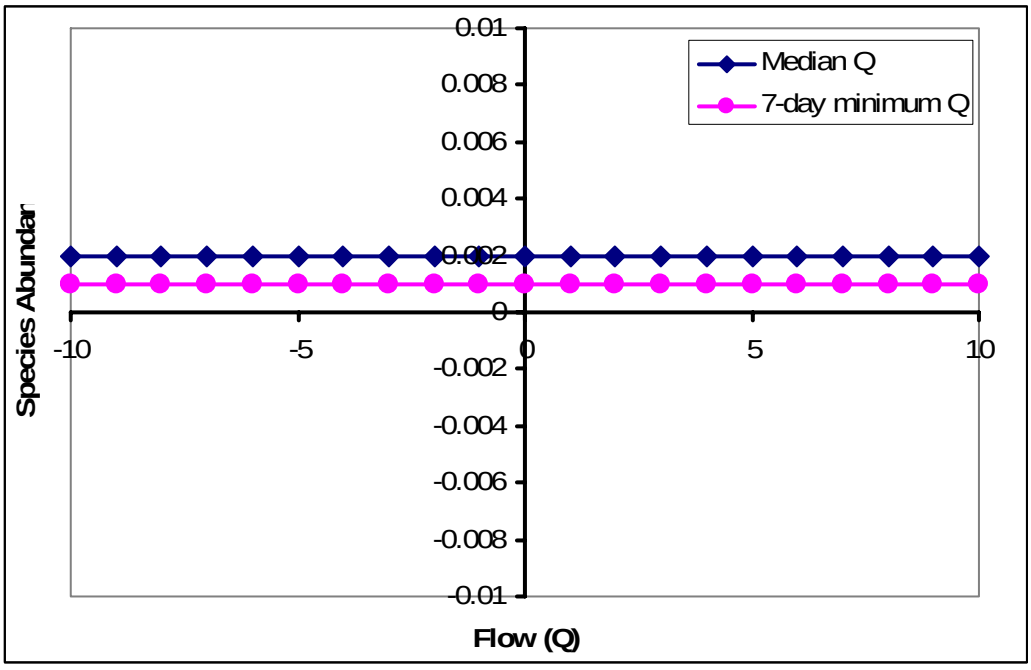

Figure 8(b) ***Sclerocarya birrea ssp caffra* (Short Rains)**

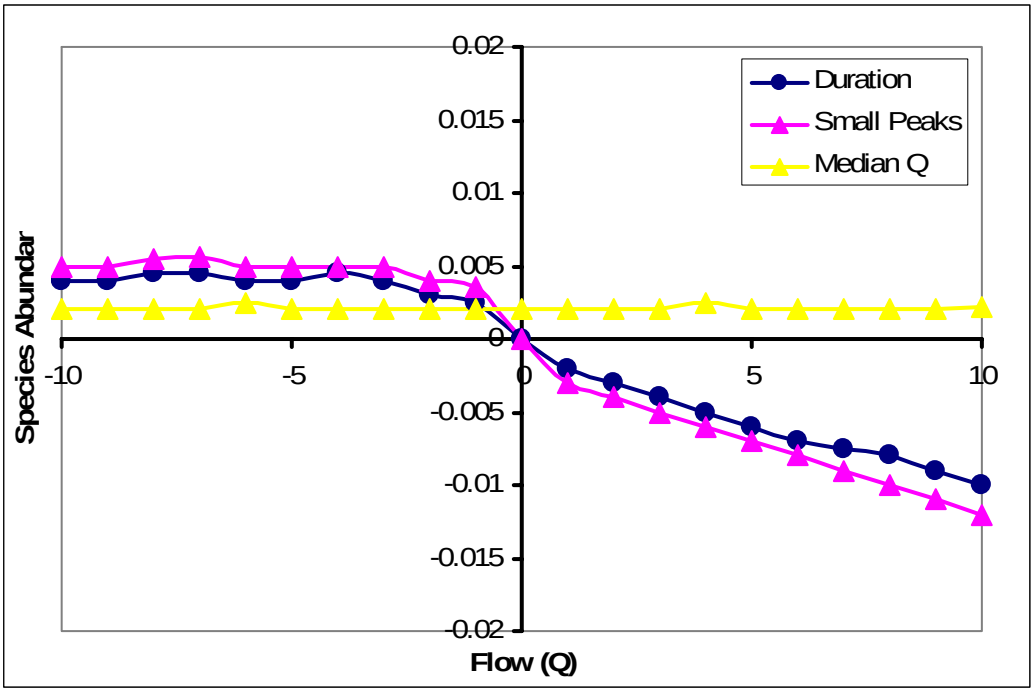

Figure 8(c) *Sclerocarya birrea ssp caffra* (Long Rains)

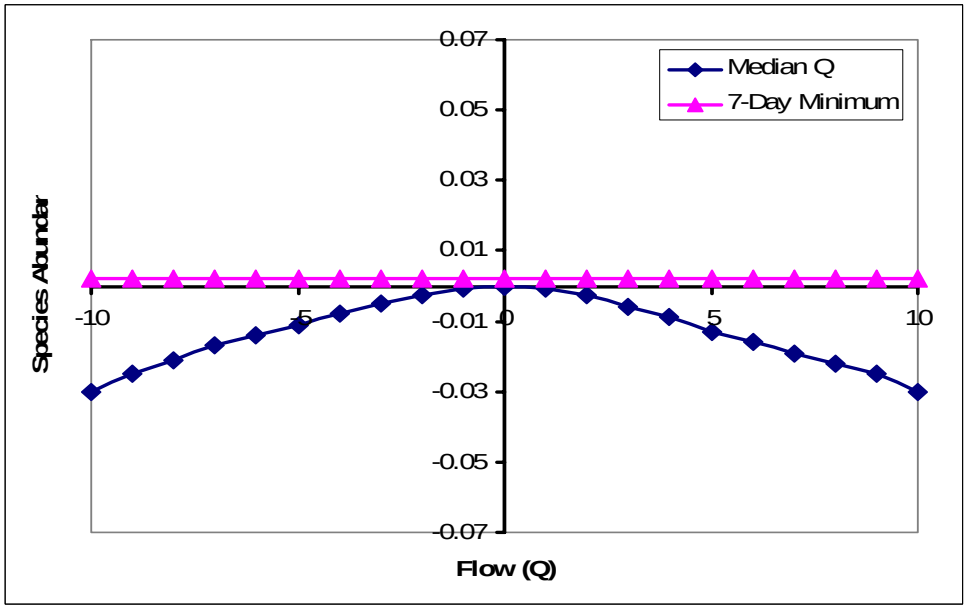

Figure 8(d) *Ficus sur* (Dry seasons 1 & 2)

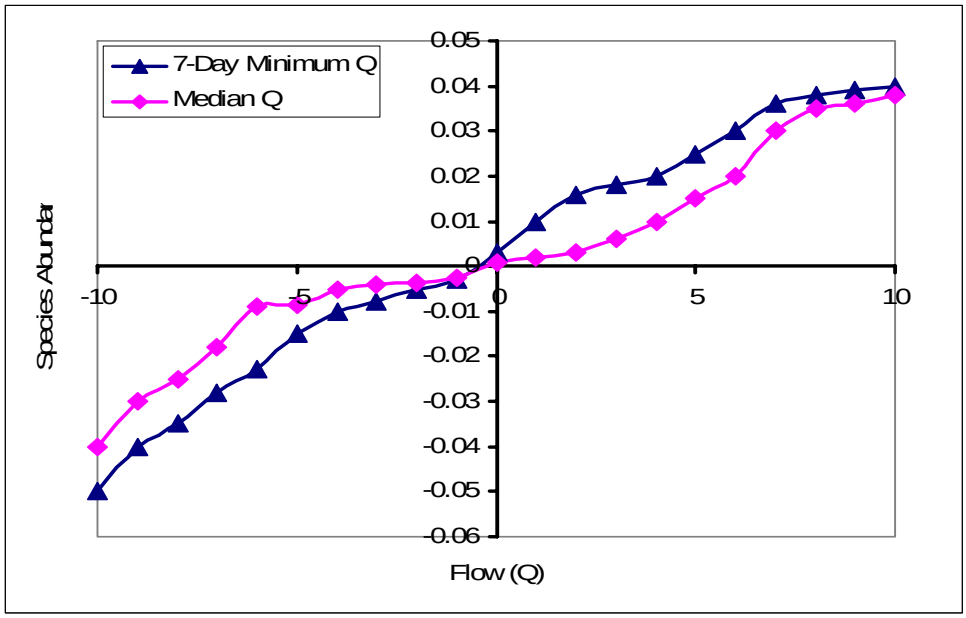

Figure 8(e) ***Ficus sur*** **(Short Rains)**

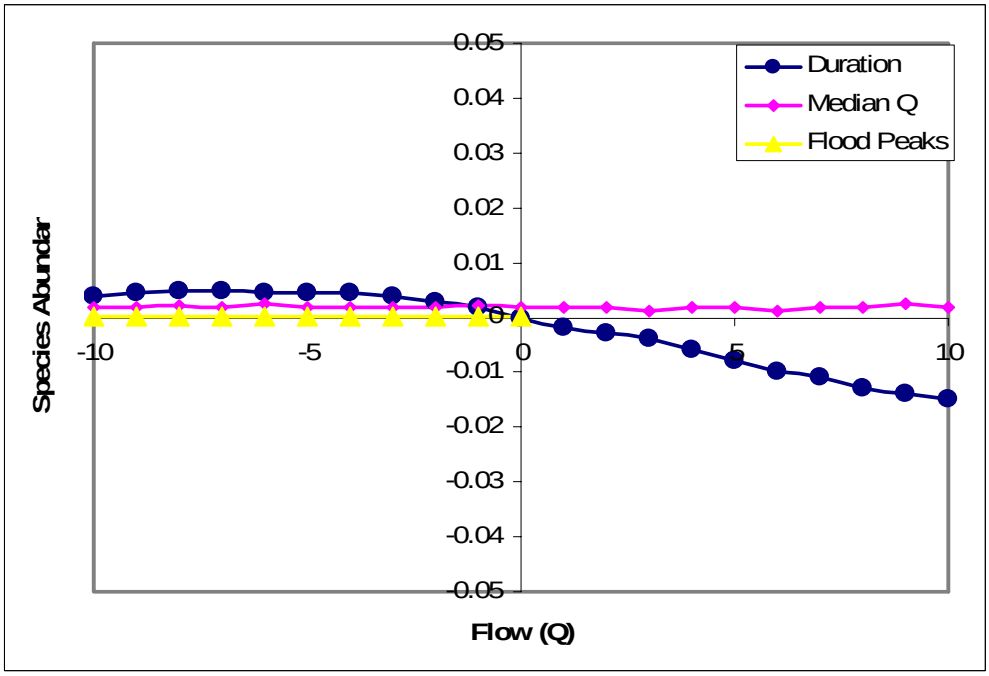

Figure 8(f) ***Ficus sur*** **(Long Rains)**

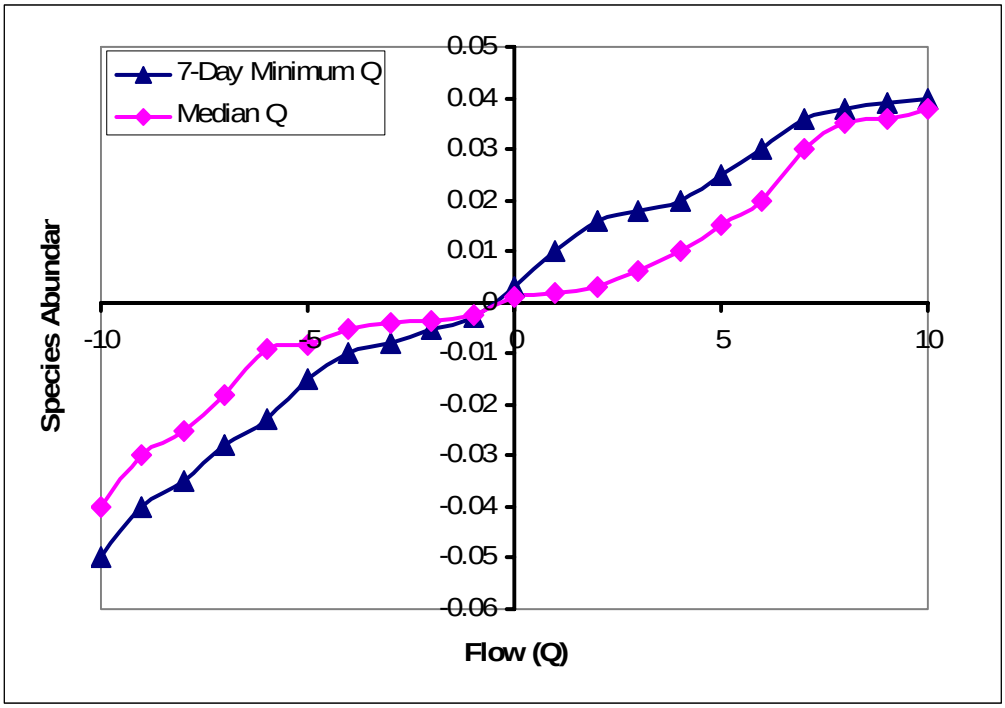

Figure 8(g) *Cyperus articulatus* (Dry seasons 1 & 2)

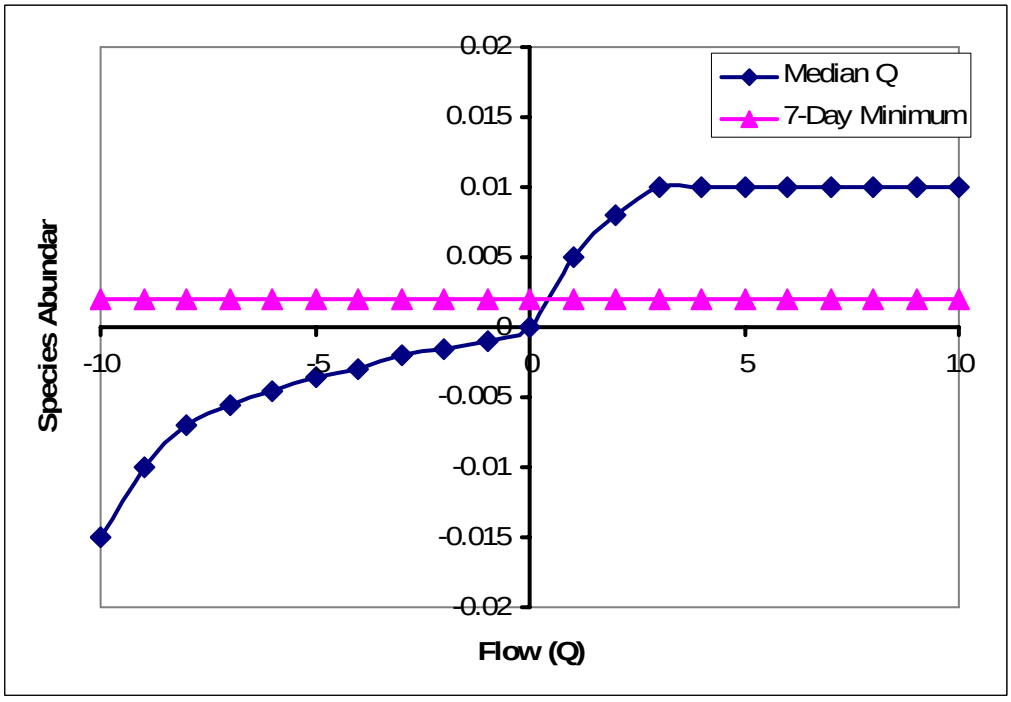

Figure 8(h) *Cyperus articularis* (Short Rains)

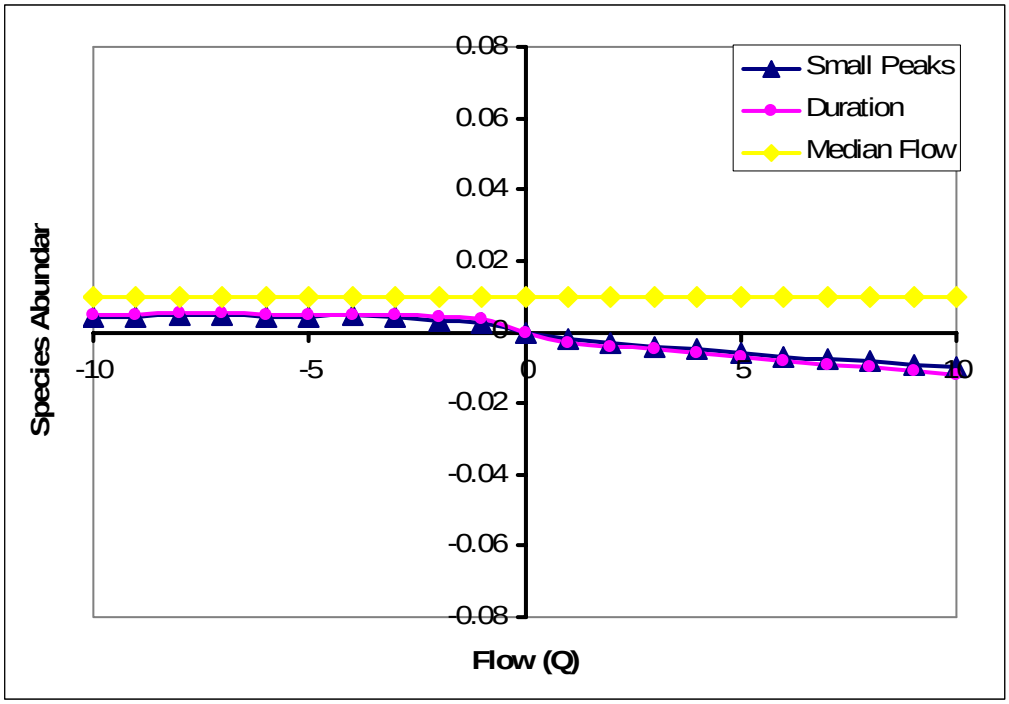

Figure 8(i) *Cyperus articularis* (Long Rains)

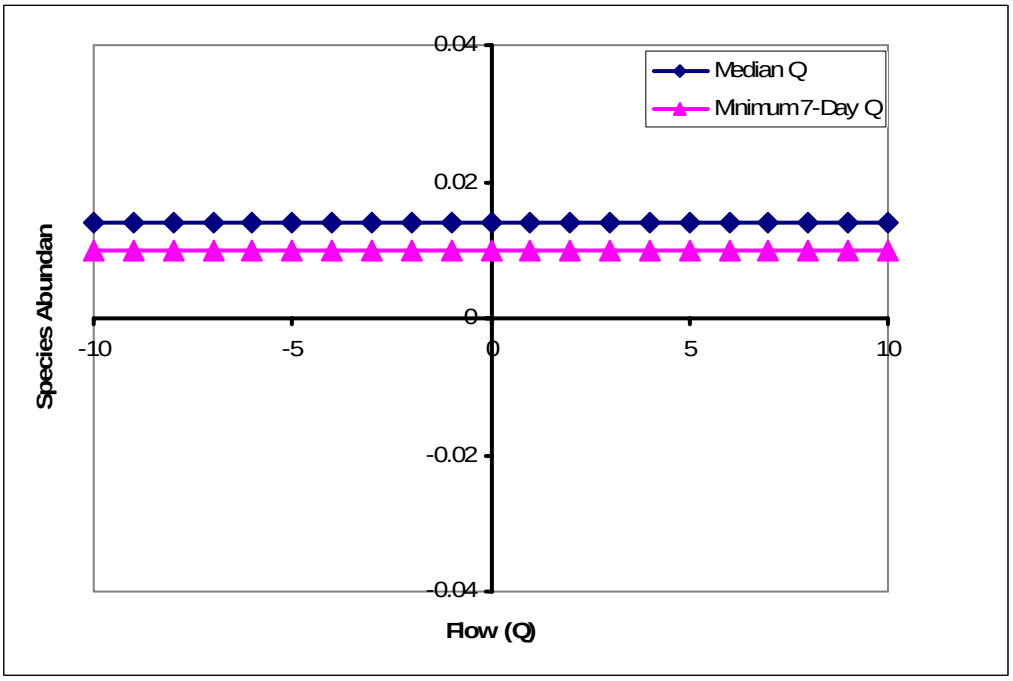

Figure 8(j) *Trichilia emetica* (Dry season 1 & 2)

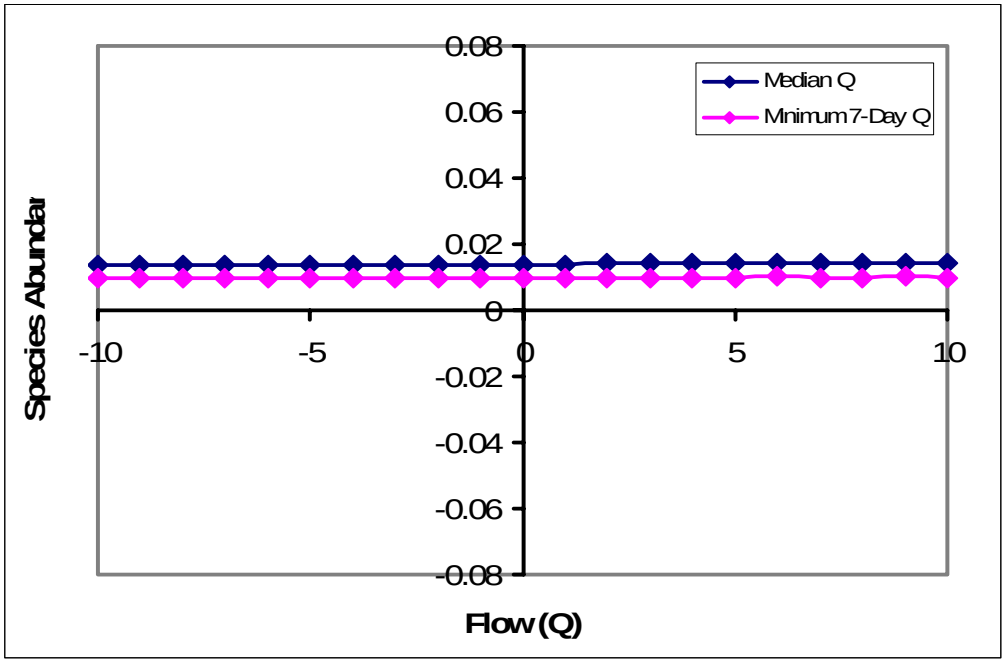

Figure 8(l) *Trichilia emetica* (Short Rains)

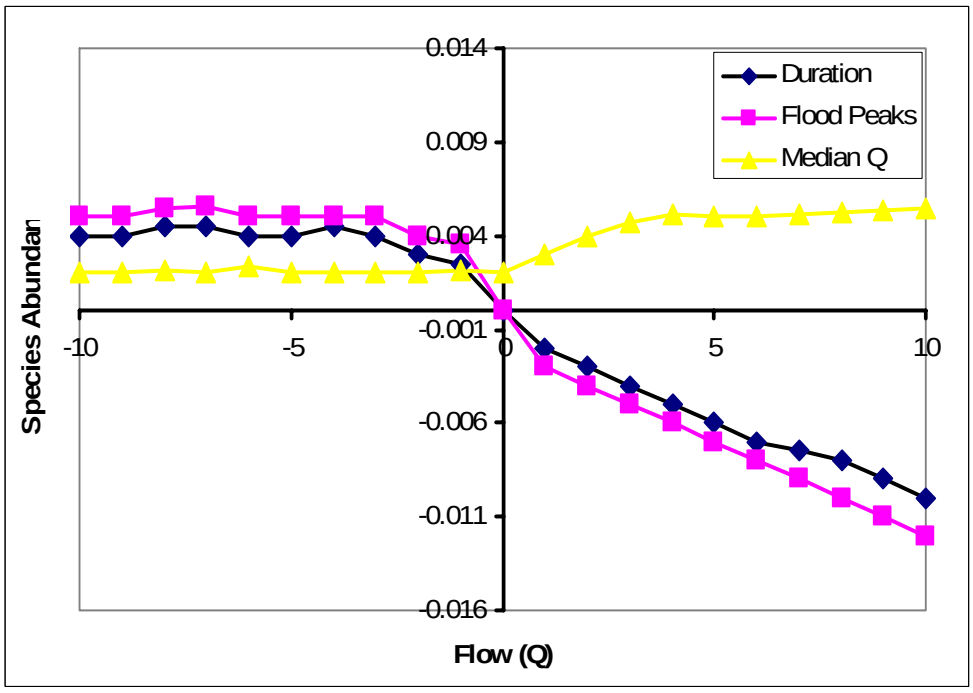

Figure 8(m) Trichilia emetica (Long Rains)

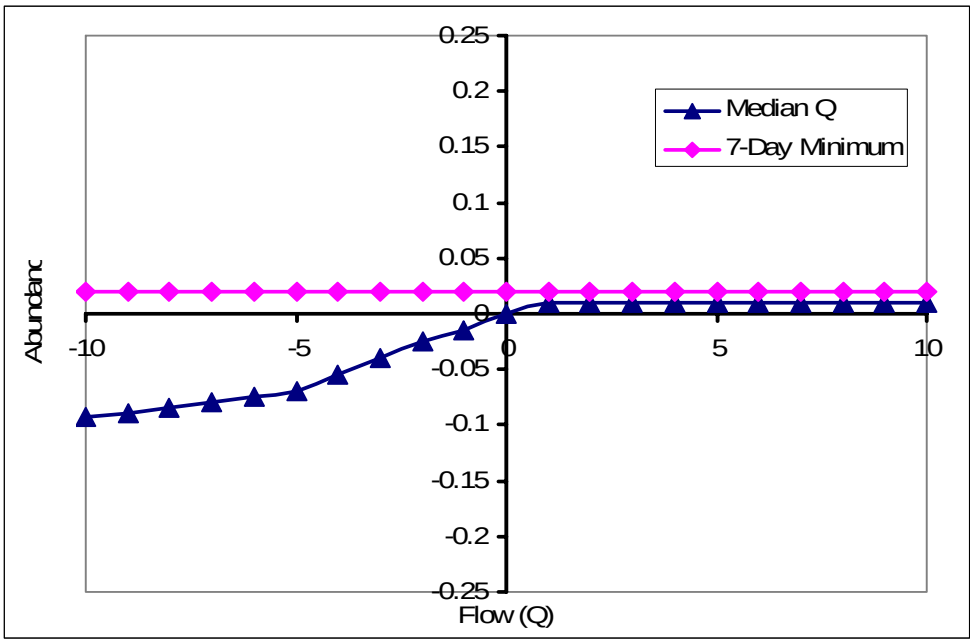

Figure 8(n) ***Kylinger elata*** **(Dry seasons 1 & 2)**

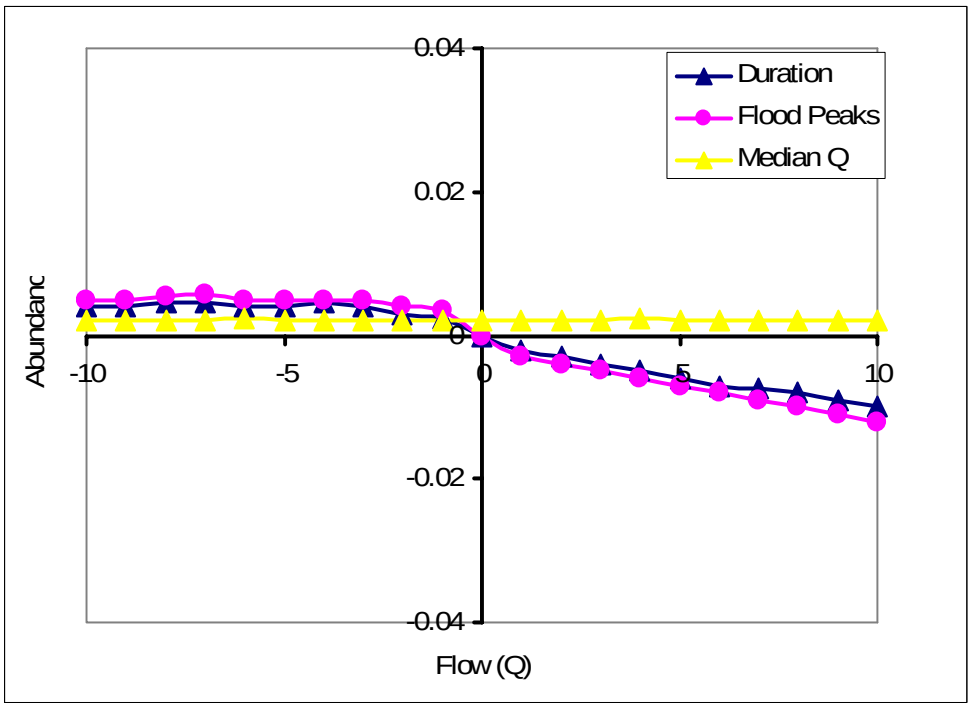

Figure 8(m) Kylinger elata (Long Rains)

6.2.4 Response Curves for Selected Species in the Rejuvenated Bedrock and Mature Lowland River Zone Pangani Basin

The representative species in this zone include *Acacia polyacantha* (dry bank tree), *Barringtonia racemosa* (wet bank tree), *Phoenix reclinata* (wet bank shrub), *Cyperus exaltatus* (wet bank herb). The response curves for the species are shown in figures 9(a-l). The **x** and **y** axes represent the present day conditions of flow and species abundance respectively and the curves show the species response relative to present day flow and abundance.

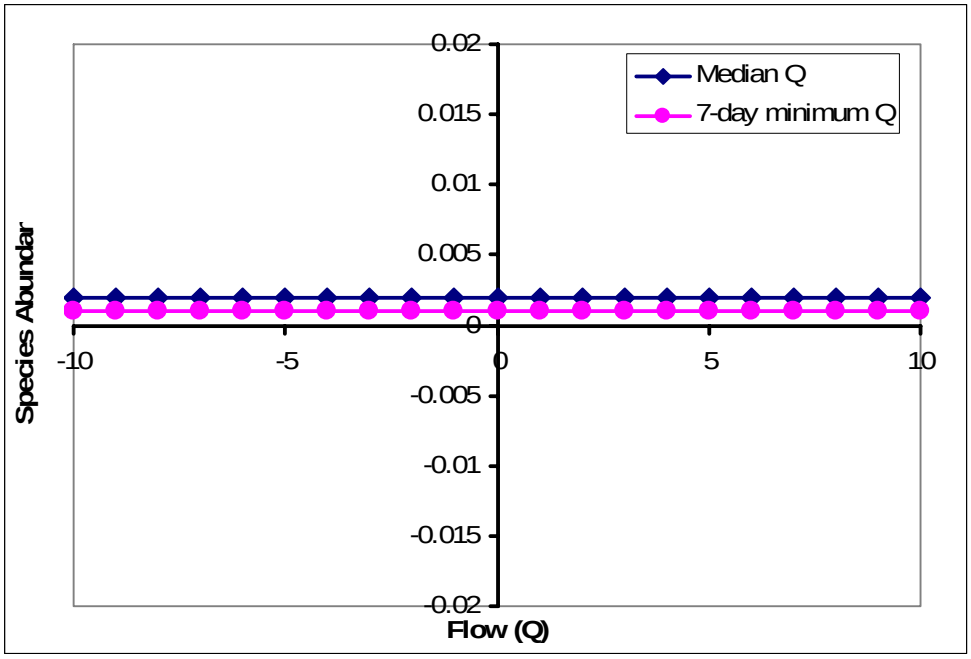

Figure 9(a) ***Acacia polyacantha*** **(Dry seasons 1 & 2)**

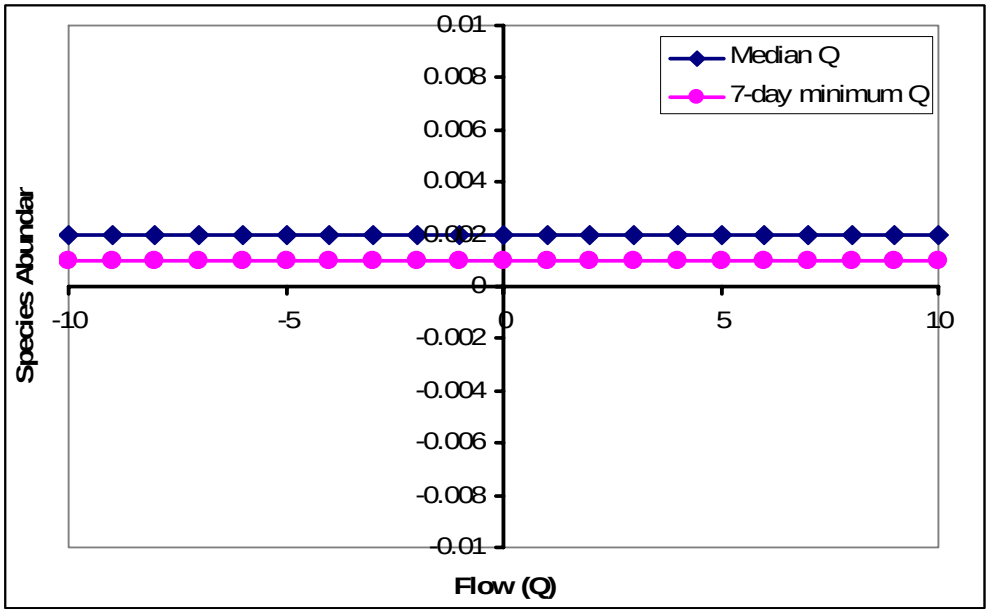

Figure 9(b) ***Acacia polyacantha*** **(Short Rains)**

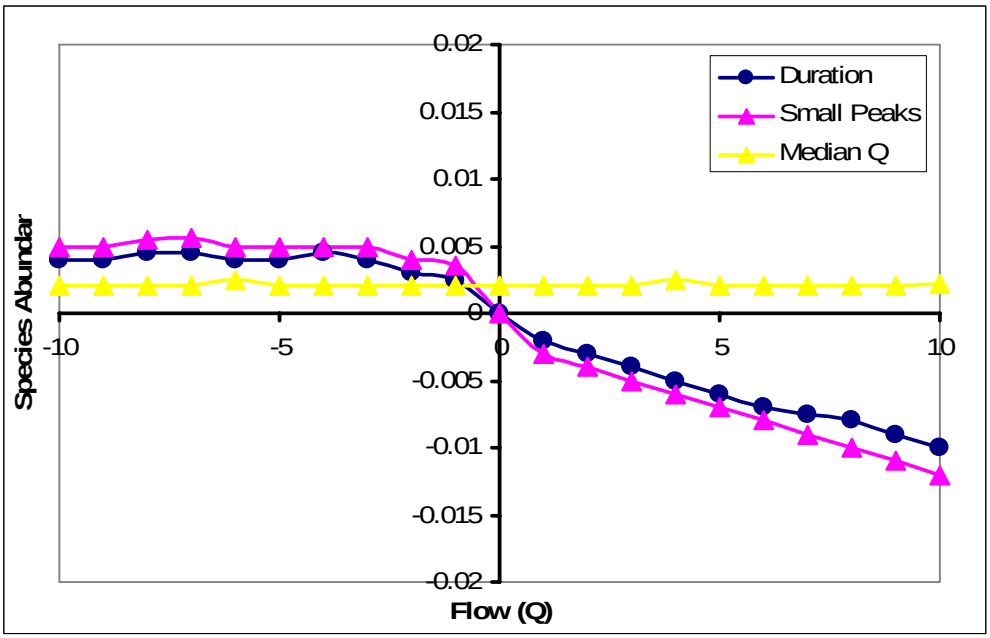

Figure 9(c) *Acacia polyacantha* (Long Rains)

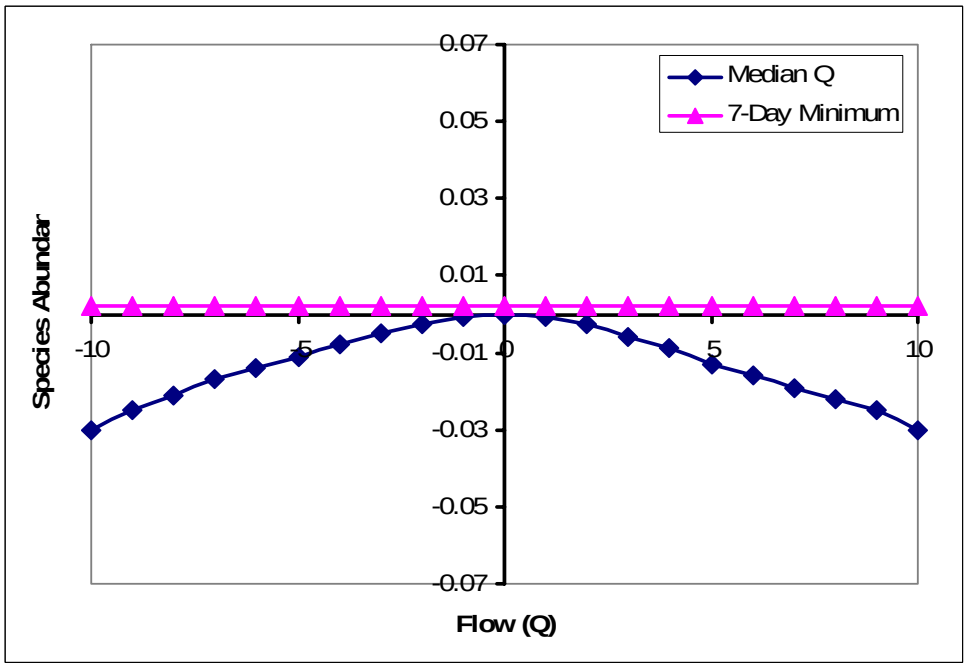

Figure 9(d) *Barringtonia racemosa* (Dry seasons 1 & 2)

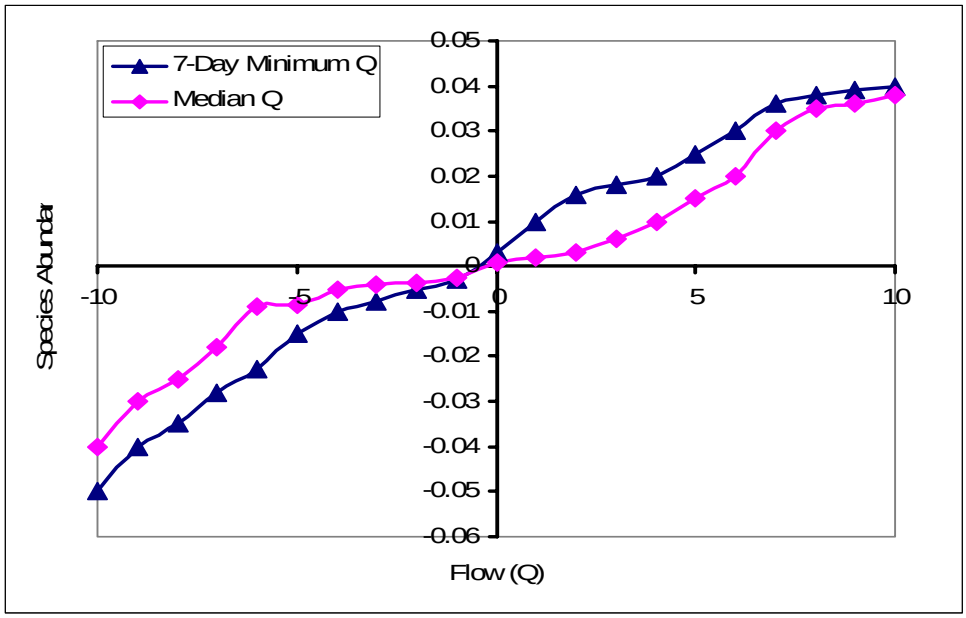

Figure 9(e) ***Barringtonia racemosa*** **(Short Rains)**

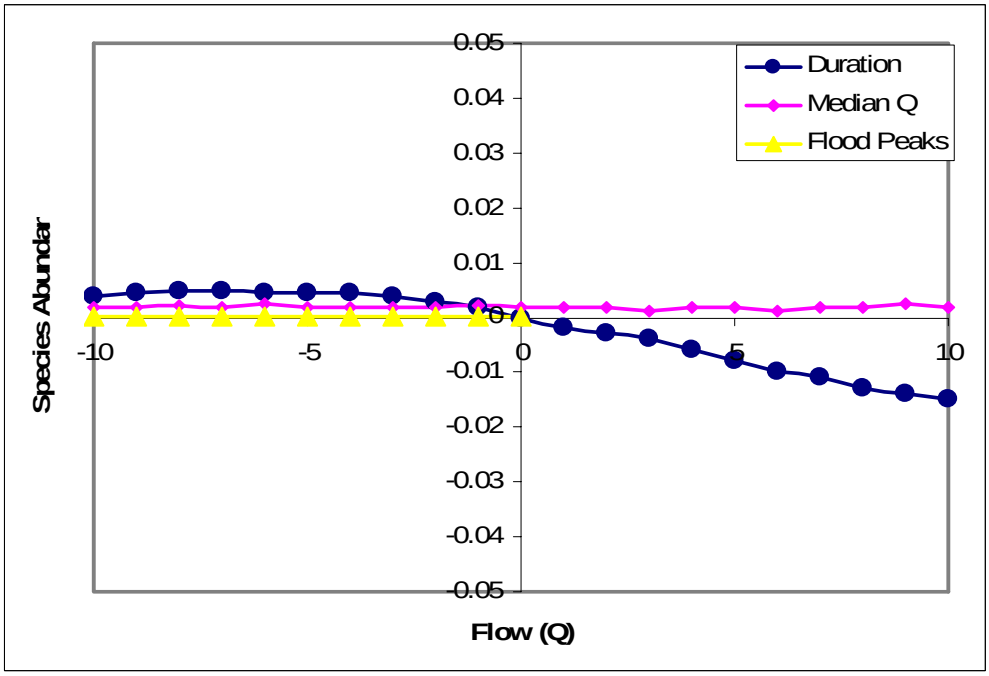

Figure 9(f) ***Barringtonia racemosa*** **(Long Rains)**

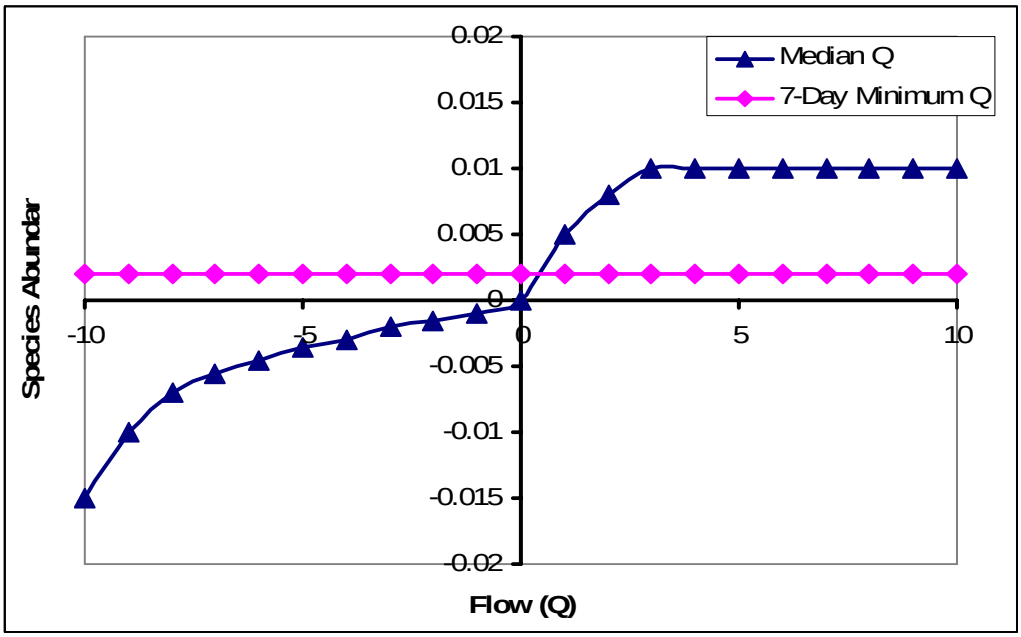

Figure 9(g) *Phoenix reclinata* (Dry seasons 1 & 2)

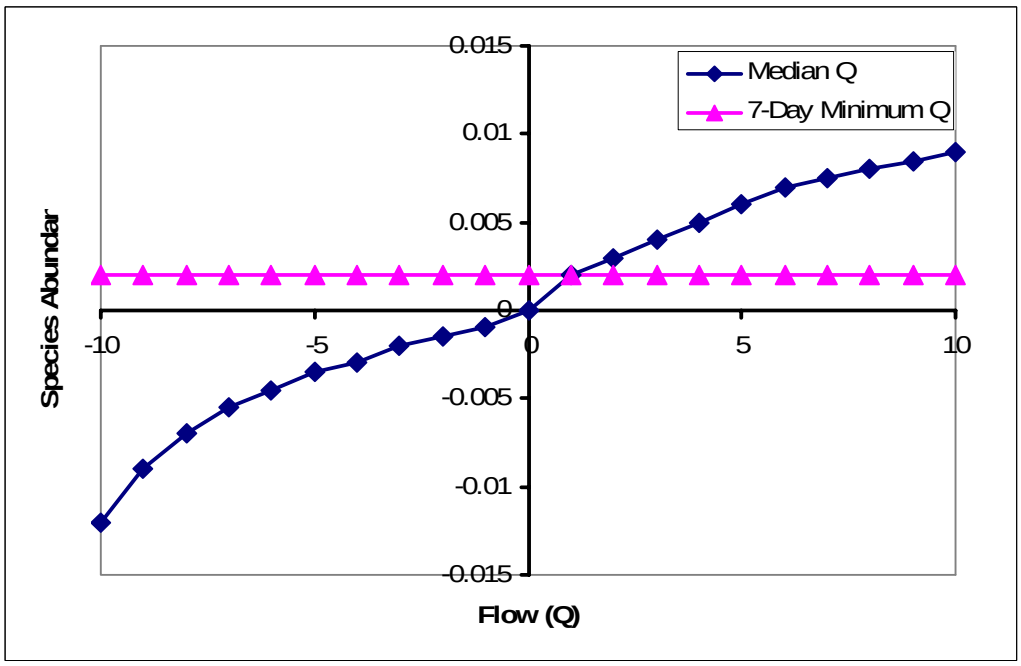

Figure 9(h) *Phoenix reclinata* (Short Rains)

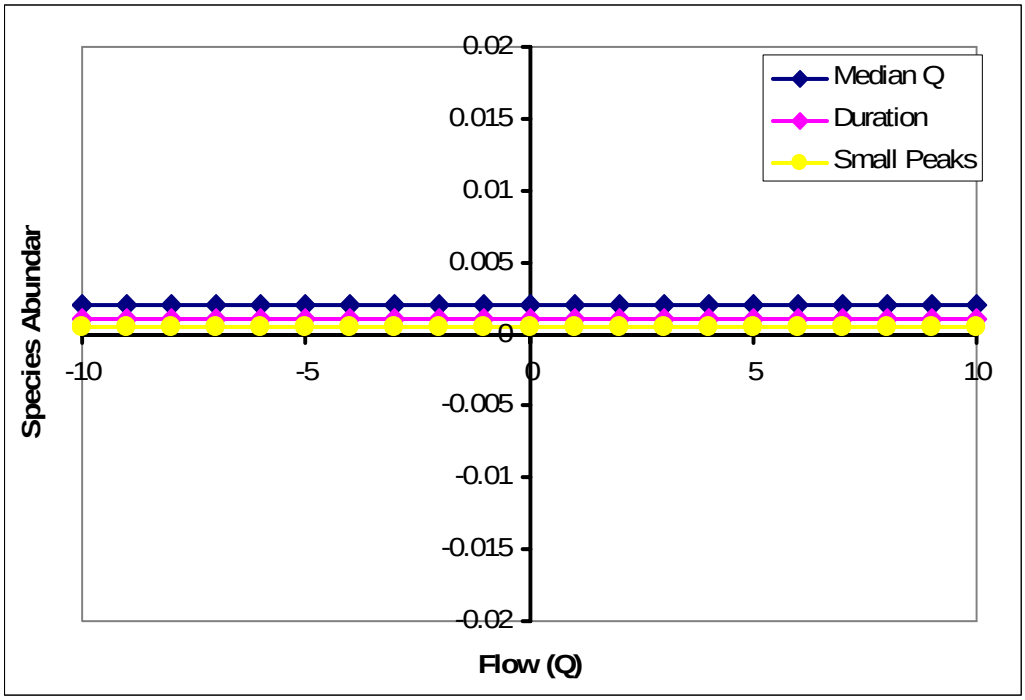

Figure 9(i) *Phoenix reclinata* (Long Rains)

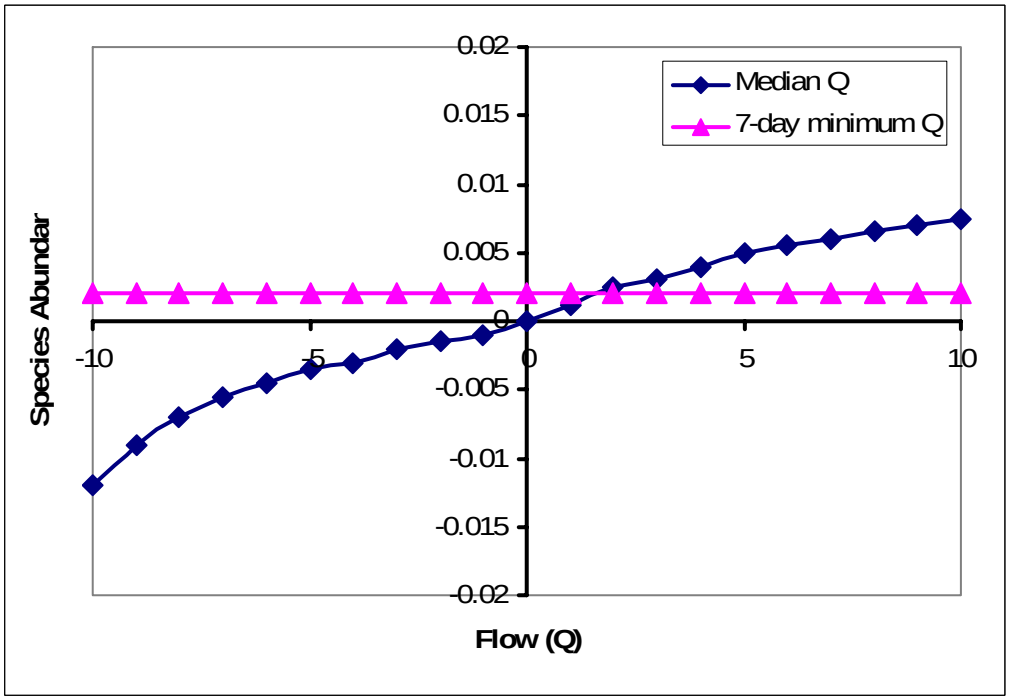

Figure 9(j) *Cyperus rotudus* (Dry season 1 & 2)

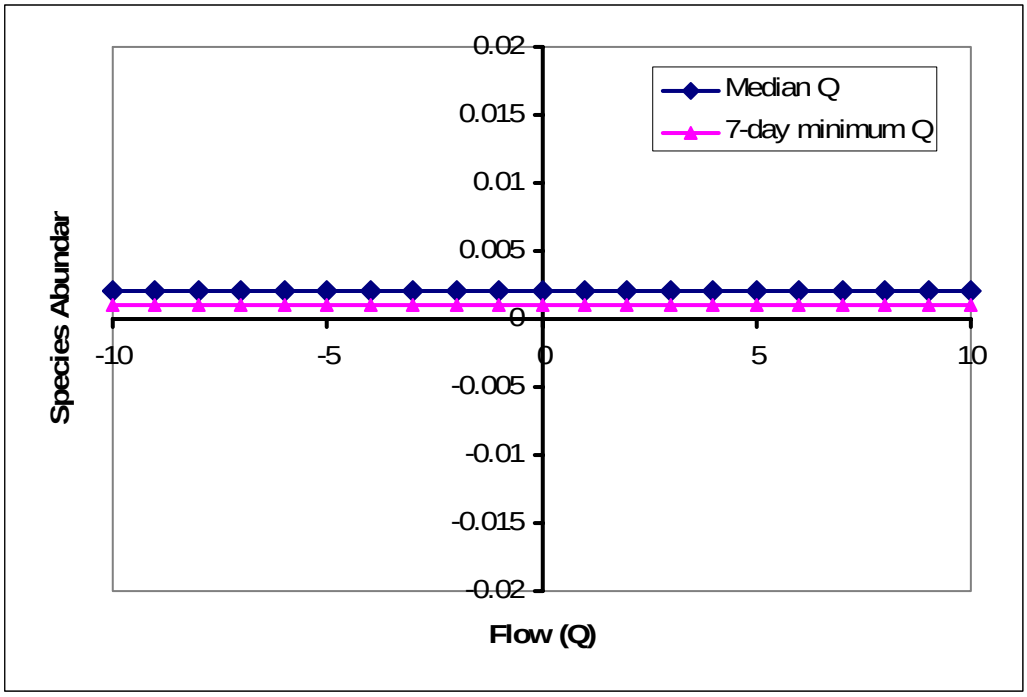

Figure 9(k) *Cyperus rotundus* (Short Rains)

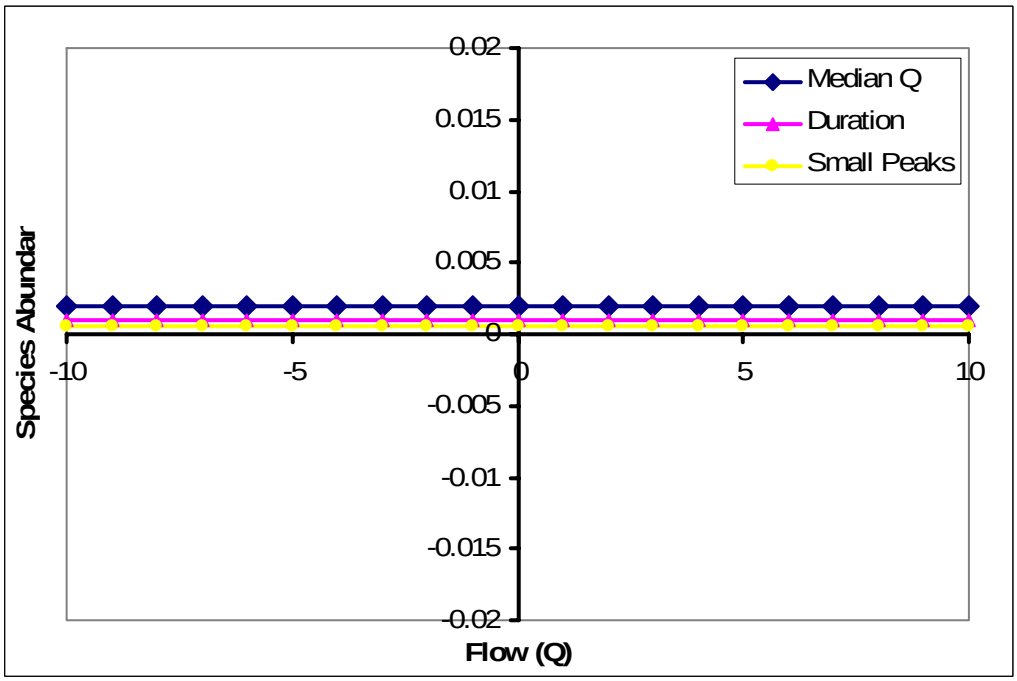

Figure 9(l) *Cyperus rotundus* (Long Rains)

6.2.5 Response Curves for Selected Species in the Estuary Zone Pangani River Basin

The representative species in this zone include *Cocos nucifera* (dry bank tree),*Rhizophora mucronata* (wet bank tree), and *Xylocarpus granatum* (wet bank tree). The response curves for the species are shown in figures 10(a-i). The **x** and **y** axes represent the present day conditions of flow and species abundance

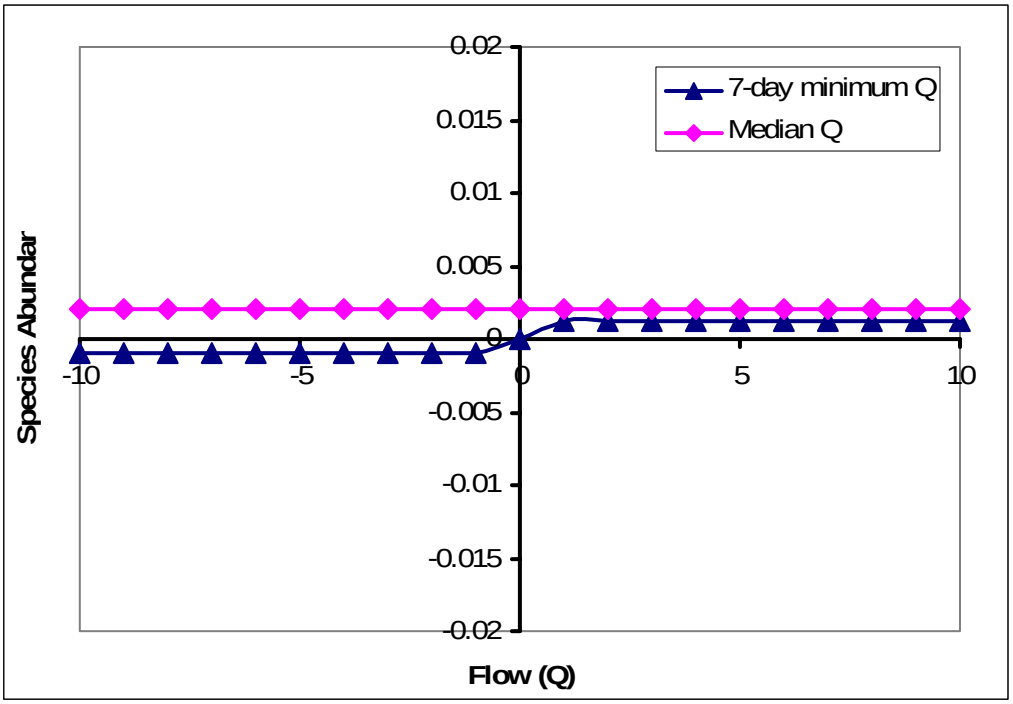

Figure 10(a) ***Cocos nucifera*** **(Dry seasons 1 & 2)**

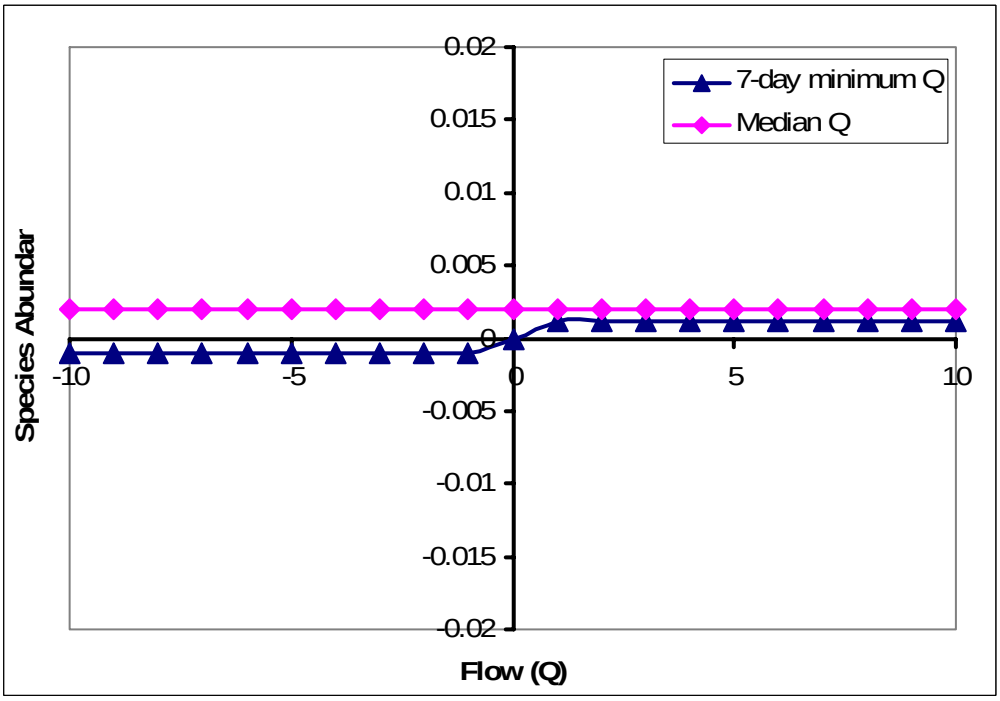

Figure 10(b) *Cocos nucifera* (Short Rains)

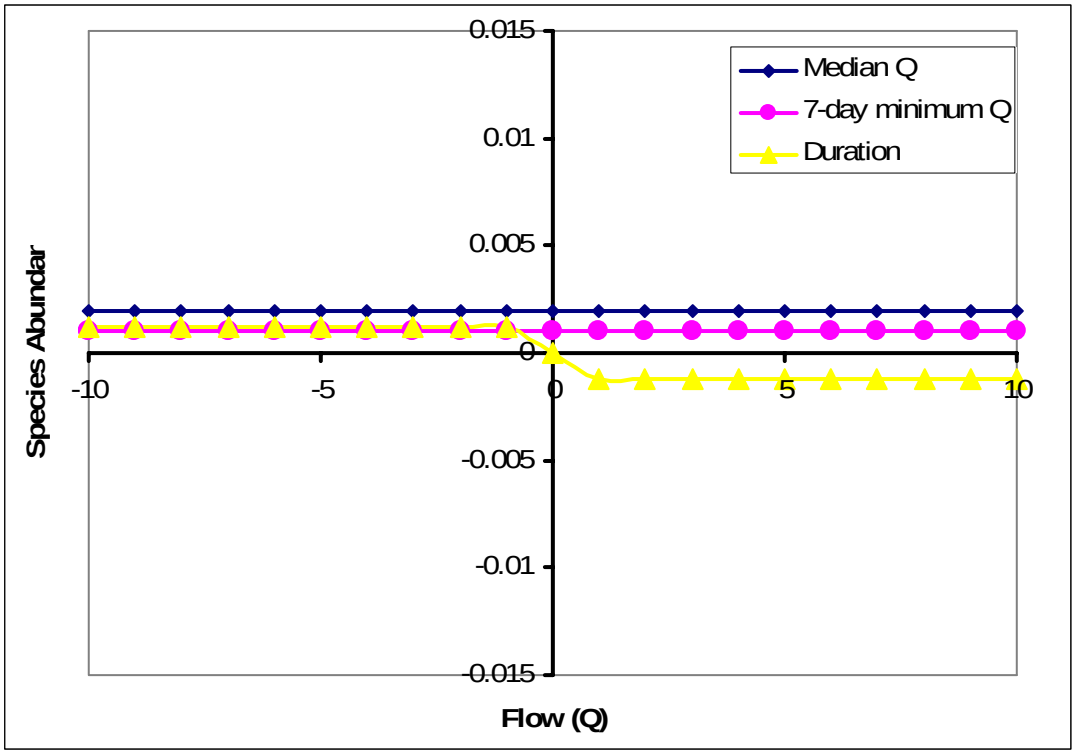

Figure 10(c) Cocos nucifera (Long Rains)

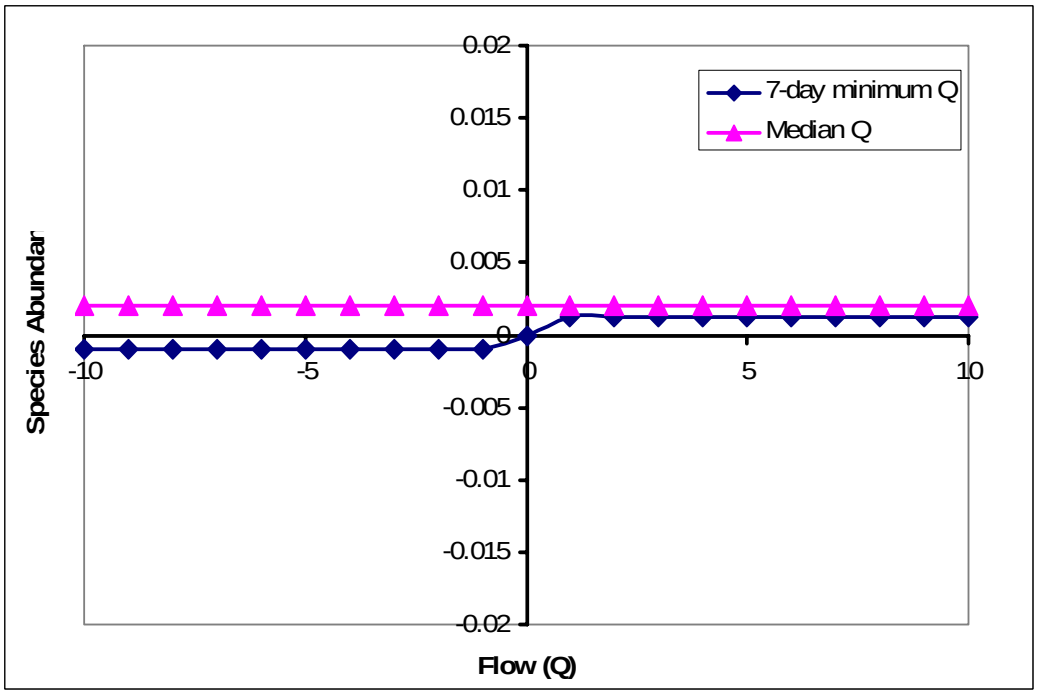

Figure 10(d) *Rhizophora mucronata* (Dry seasons 1 & 2)

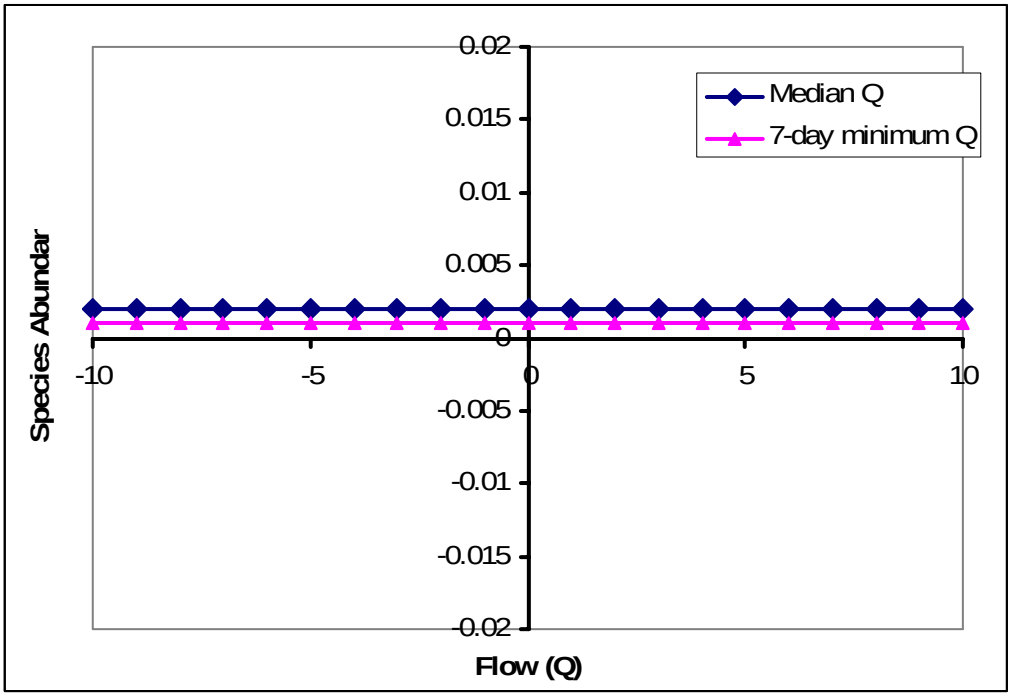

Figure 10(e) *Rhizophora mucronata* (Short Rains)

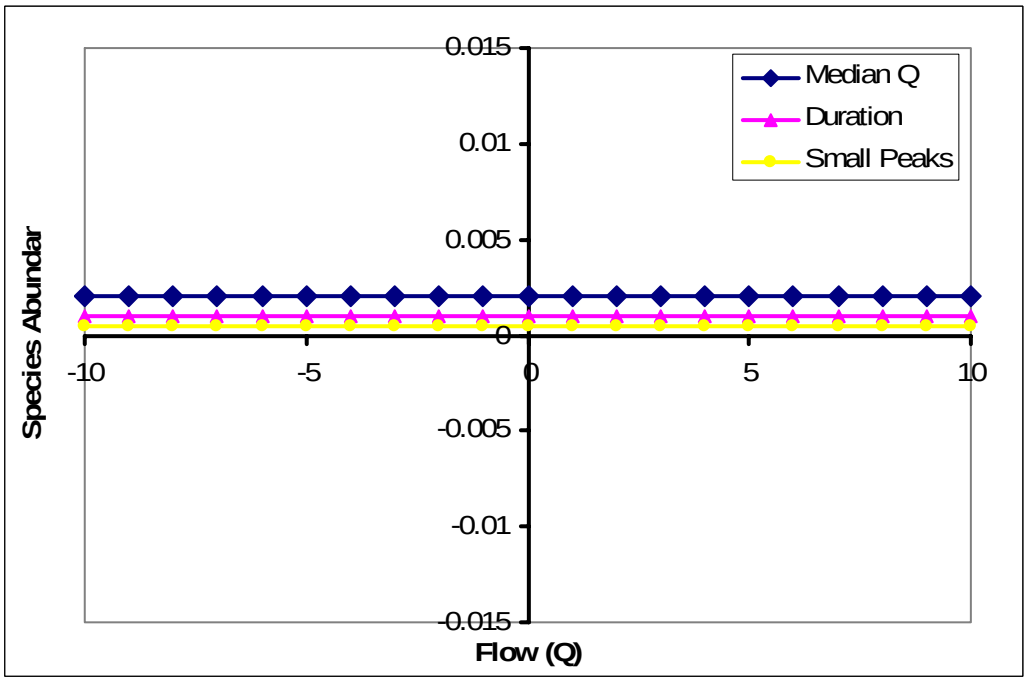

Figure 10(f) *Rhizophora mucronata* (Long Rains)

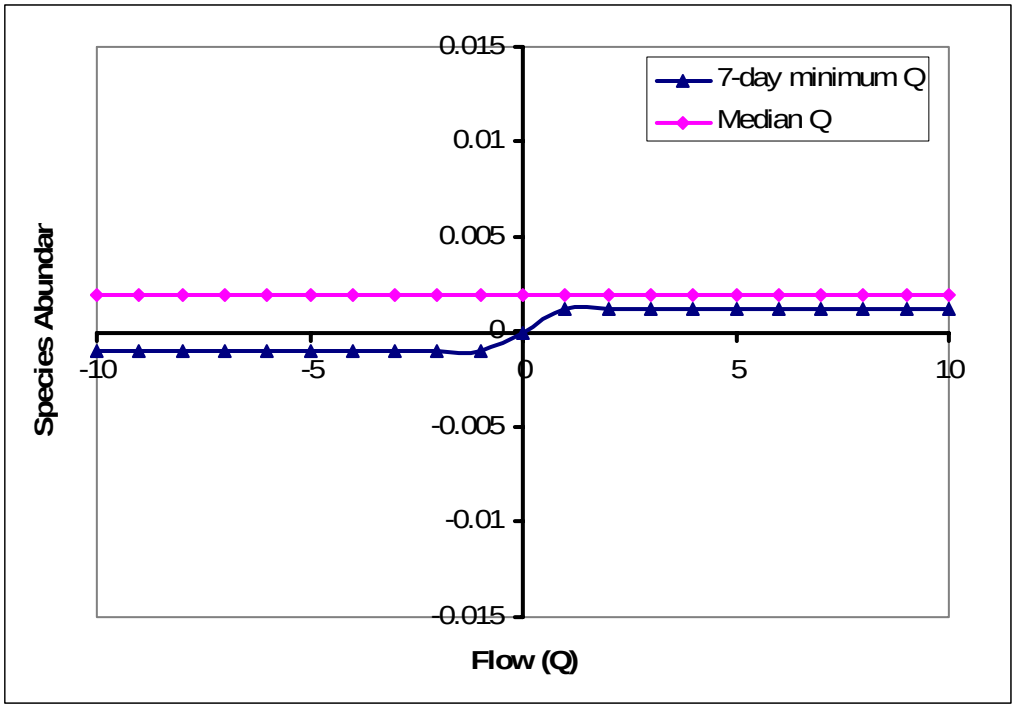

Figure 10(g) *Xylocarpus granatum* (Dry Seasons 1 & 2)

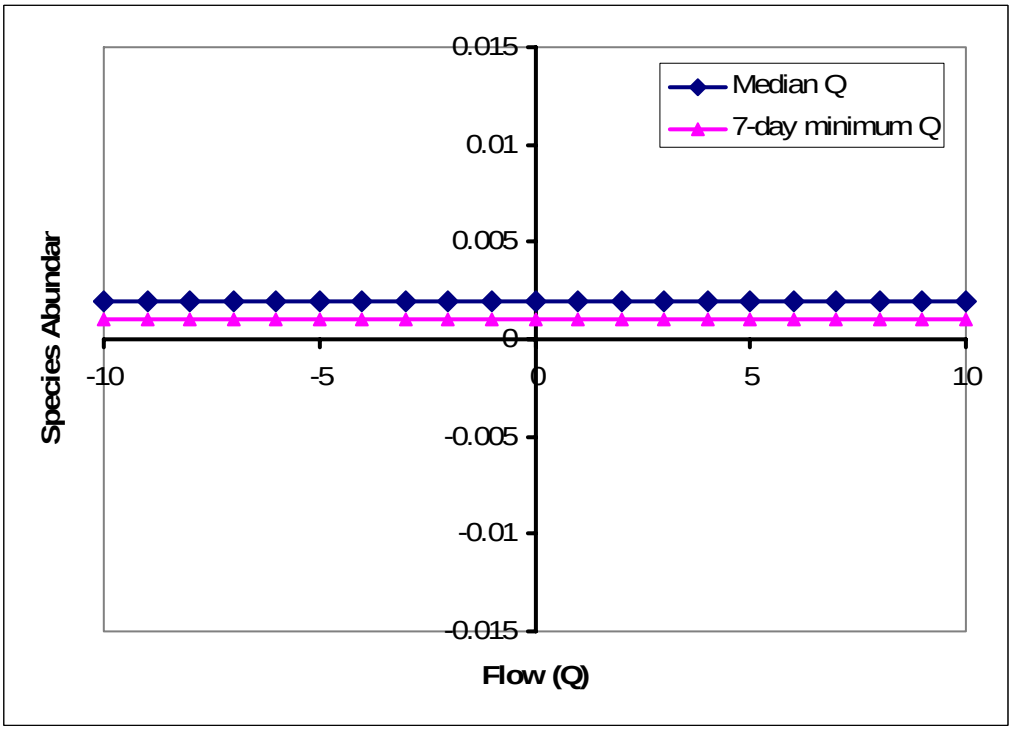

Figure 10(h) *Xylocarpus granatum* (Short Rains)

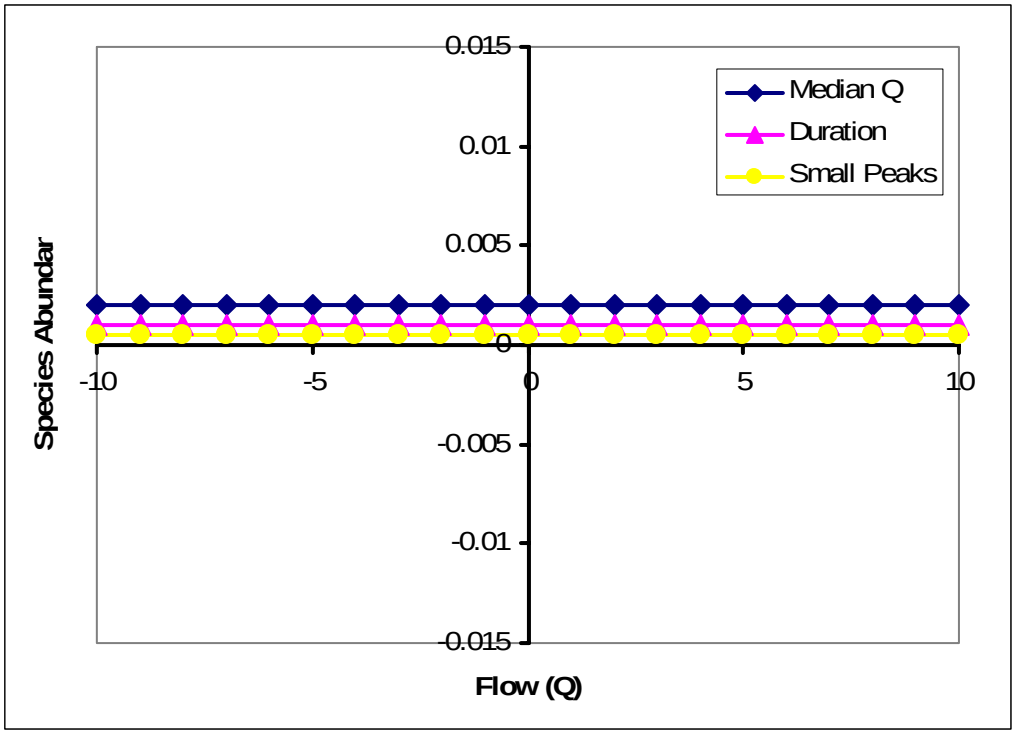

Figure 10(i) ***Xylocarpus granatum*** **(Long Rains)**

7.0 CONCLUSION AND RECOMMENDATIONS FOR FURTHER RESEARCH

Most of the species of the aquatic system are likely to be impacted more by decreases in the 7-day minimum flow and to some extent the median discharge especially in the dry season. Both species may be affected by duration of flood either negatively or positively. The wet bank species will experience higher impact from fluctuations in the frequency of small flood peak. Frequent flood peaks can suppress regeneration of most wet bank species due to frequent wash out of seedlings and seeds. Deep rooted dry and wet bank species can withstand reduced median flow and sometimes reduced 7-day minimum flows during the dry season. Frequency of flood peaks and prolonged flooding during the rain season (flooding duration) will likely suppress wet and dry bank species which are not adapted to flooded conditions through possible suffocation. The dynamics of flow regimes will therefore influence survival of plants differently depending on the characteristics of plant species. Clear determination of the representative plant species in the four lateral sections of the river i.e. water column, wet bank and dry bank is necessary for more clear understanding of the different responses by different species. Such achievements can be based on intensive field based studies and monitoring of vegetation distribution in relation to environmental processes. Further studies therefore should focus on determining the environmental correlates of different plant species distribution through field studies to be able to filter out the impacts of different water regimes from other environmental factors. Proper choice of representative species in the different ecozones require a through analysis of the ecologically

and socio-economically important plant species in the different ecozones calling for more detailed studies of such species.

REFERENCES

IUCN 2006a. Pangani Basin: A Situation Analysis. IUCN Eastern Africa Program Office. 103 pp

IUCN 2006b. IUCN Water and Nature Initiative Pangani Basin River Health Assessment 202 pp

Kamugisha, S. G. Lugomela, A. Maggid, B.M. Clark, K. Hutchings, L. Benno, D. Salum, F. Mbago and S. Mukama and E. Materu 2006. Pangani River Basin Flow Assessment Initiative Estuarine Health Assessment Report (Draft Report). Pangani Basin Water Office 115 pp

Munishi PKT. Forest Ecology – Compendium 120pp

PBWO/IUCN 2007. Pangani River System – State of the Basin Report – 2007. PBWO Moshi Tanzania and IUCN Eastern Africa Regional Program, Nairobi Kenya 47pp

Wang, Y., Bonynge, G., Nugranan, J., Traber, M., Ngusaru, A., Tobey, J., Hale, L., Bowen, R., and Makota, V. 2003. Remote sensing of mangrove change along the Tanzania coast. *Marine Geodesy* 26: 1014.