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Theme section : Man-nature relationship

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About Guest Editor

Mr. Vishwas Sawarkar is Trustee of Ecological Society, and Retired Director, Wildlife Institute of India, Dehradun (WII). Mr. Sawarkar worked with the USDA Forest Service and the US Fish and Wildlife Service (Projects in India and sharing experience in USA)-Conservation of biological diversity in protected areas and forested landscapes. He was part of the first teams to work in Project Tiger in India- the Melghat Tiger Reserve, Maharashtra (1973-79). He was also the first Dean of the Faculty of Wildlife Sciences, WII and retired as Director WII. He is currently consultant for various wildlife management related projects/initiatives.

Reviewers

The papers titled 'Research' in this journal have gone through a double-blind peer review process from eminent researchers in the respective field. All other contributions have also undergone peer review from experienced reviewers.

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Foreword

This journal has always upheld the importance of looking at man-nature relationship in a holistic way, and believed that the foundation of this thought will lead us to re-design the human world towards sustainability.

This issue of the journal is no exception. It has a themed section which contains some less-explored aspects of the man-nature relationship. It includes : a research paper on biomonitoring of aquatic ecosystems in Meghalaya, an article proposing medicinal plant crops as a solution to mitigate man-wildlife conflicts near Protected Areas, and an article about the unnoticed man-wildlife conflicts in urban areas. A more comprehensive introduction to these articles appears in the Foreward to the themed section.

We are privileged to have Mr. Vishwas Sawarkar, Trustee of Ecological Society, as the guest editor for the special section on man-nature relationship. Mr. Sawarkar worked with the USDA Forest Service and the US Fish and Wildlife Service (projects in India and sharing experience in USA) related to conservation of biological diversity in protected areas and forested landscapes. He was part of the first teams to work in Project Tiger in India - the Melghat Tiger Reserve, Maharashtra (1973-79). He was also the first Dean of the Faculty of Wildlife Sciences, Wildlife Institute of India, Dehradun (WII) and retired as Director WII. He is currently a consultant for various wildlife management related projects and initiatives.

In this issue, we continue to report the work done during 2014-15 in the Panshet dam catchment by Ecological Society under a grant by Global Forest Watch. This issue includes the final installment of two articles. The first article documents the vegetation character and plant diversity in the Panshet catchment. The article identifies rare, endemic and specialist species in the catchment and makes specific recommendations for their conservation. The second article proposes a set of templates that would be highly useful for planning ecological restoration in degraded forest sections of Western Ghats. The articles draw upon rich, practical field experience of the authors working for the past several years in Western Ghats. We hope both these articles will be welcomed by academics and ecological practitioners working in the region.

Finally, we have reprinted an article by Prof. Prakash Gole which appeared in the 1993 issue of this journal, along with an analysis in the present context. Prof. Gole had written an open letter to team members of the Indian delegation to the Rio Conference in 1992. This conference was the first attempt by the global community to address Climate Change. His article brings up a variety of issues which continue to be relevant even today and demonstrates his visionary thinking. The analytical note accompanying this reprint poses the question whether the last 25 years have seen any progress at all on the front of Global Environmental Democracy.

Complex technology, increased economic integration, and global homogenization are sacrificing rich biodiversity and the harmony between man and nature that our previous generations grew up with, thus precipitating an environmental crisis. Relevant education, societal awareness and political interest in sustainability are sorely lacking. Hence, the Ecological Society continues along the path of generating more awareness by visiting the man-nature dynamic as comprehensively as possible.

Yogesh Pathak
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One Year PG Diploma in Sustainable Management of Natural Resources And Nature Conservation

Program Highlights :

The Ecological Society conducts a one year program which includes class room sessions, case discussions and field experience through camps and field work. Classes are conducted every Saturday between 3:00pm to 8:00pm in the Society's office. Students have access to the Society's library which has a unique collection of books, journals and periodicals on ecology and environment. The program offers students an opportunity for intellectual interaction with experts in related fields.

The program is academically rigorous and substantial extra reading is expected from students. Assignments and field work reports require team work and extra hours of work besides the Saturday sessions.

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- **Ecosystem Management and Restoration** : Basic Principles of Management, Financial management of projects and costing, Environmental Economics, Soil Science, Restoration Theory and Practice
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- Coastal Ecosystem, 4 days camp
- Forest Ecosystem and River Ecology, 2 days excursion
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Duration : One year (June 2017 to March 2018)
Course Schedule :
Days : Saturday **Timing :** 2:00 pm to 7:00 pm, **Field visits** on Sunday

Admissions start from May 2017

Foreword to the Special Section on Man-Nature Relationship

The relationship between the modern man and wildlife is as old as the modern human race. Typically, it is steeped in the positives and negatives. The negatives by far tend to outweigh nature's munificent largesse to muddy our perception of the ancient kinship between man and fellow creatures notwithstanding the priceless and free ecological services we enjoy. Not surprisingly though after Darwin's Origin of Species alongside the serious attempts at taming the wilderness, the immensity of the contours of positives in the relationship are taking shape with clarity. The spurt of progress in science during the post 1980s in particular is seeking to turn the tide in favour of wilderness and wildlife led by the inclusive concept of biological diversity and its role in support of the future and the quality of human life. The Ecological Society since its inception has espoused and professed that emerging interest.

In this issue of the Journal there are three papers that address some of the important aspects of these relationships. The subjects and the ecosystems addressed vary widely from those addressing challenges of farming in the neighbourhood of ecologically rich forests, to probing the quality of fresh water ecosystems for the benefit of people and then on to centers of urbanization and need for making amends for its fallout on wild creatures. The common feature across these papers however is the hope, determination and ways of overcoming the predicaments by employing technology, experiments and adaptations.

The research relating to freshwater streams in Meghalaya has sought to establish the role of biomonitoring – employing presence/absence of some of the native macroinvertebrates alongside abiotic parameters to adjudge water quality and assess watershed conditions. Using such tools and perspectives can develop the collective mindset through capacity building. Fresh water constitutes our lifeline and water quality is critical for human health. It supports significant economy via the freshwater fisheries in India with an annual catch of 6.57 million tonnes during 2014-15.

Crop raiding by wild herbivores is a refrain in the proximity of one of the finest tiger reserves in the country – the Tadoba-Andahri located in Chandrapur district. The study centered on this ecosystem seeks to mitigate the problem. It explores the economics and the advantages of raising some of the non-palatable medicinal plants in trade that are of little interest to wild animals as opposed to crops that are routinely raided. A four phased participatory model includes an easy to follow process ranging from the selection of species to establishing market linkages for sale of value added produce. What is more, the process is recorded in the local language, Marathi in a booklet that farmers can use.

The third paper describes with examples the reality of rapid urbanization causing unrecognizable changes in habitats of species that are otherwise adapted to human presence. Infrastructure designs that facilitate various segments of development and large scale introduction of exotic plants have had varied impacts depending on the sensitivities of different native species. While the paper narrates such conflicts by their categories, it explains the processes for mitigation involving skills of informed stakeholders, the importance of awareness generation, it stresses on the need for planting and care of native tree species, use of adaptive engineering and much more. Enlightened approach has an important place in developing urban centers that care for shared spaces with wildlife. It would be amply clear that wildlife conservation and conflict resolution is not applicable just to India's wilderness and the abutting rural ecosystems. The urban centers also need to share that responsibility in our own interest and to honour our Constitution in letter and spirit.

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Special Section : Man-Nature Relationship

Research Paper

Filling in the Gaps for Aquatic Ecosystem Conservation – Biomonitoring for Baseline Information and Capacity Building in Meghalaya, India

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Abstract

This paper describes a stream biomonitoring program that builds capacity in undergraduate college students in the field of freshwater ecology and conservation. The program involves sampling of aquatic macroinvertebrates and hydrological parameters in streams of the state of Meghalaya, India. Several colleges from Shillong initiated short-term, one-year and long-term biomonitoring of streams in East Khasi Hills and Ri-Bhoi districts. Nine stream locations sampled over October-December in 2014 provided a snapshot of physical and biotic conditions, thus enabling the examination of spatial trends in water quality parameters and aquatic biota. A year-long sampling study from 2014-2015 provided a seasonal view of stream parameters at Lwai (clean) and Umkaliar (moderately polluted) streams. Results from both sampling sets suggest that turbidity negatively affected the richness of pollution sensitive taxa. Dissolved Oxygen values were lower in polluted streams and were non-significantly lower in summer than in winter. After an initial training in the field, the sampling was conducted by college students under supervision from their lecturers. Data obtained on macroinvertebrates adds to the sparse information available on stream ecosystems in the biodiversity-rich northeast Indian region. We hope the paper provides a template for monitoring of vital ecosystems in this and similar regions.

Acknowledgements

The inception of this study was made possible with grants from Rufford Foundation, UK to Sonali Saha in 2014 and 2016. Amartya Saha was supported by the USAID-funded Global Water for Sustainability Program, Florida International University. A Fulbright-Nehru Professional Excellence Award to Sonali Saha in 2015-2016 facilitated the strengthening of biomonitoring network. We also thank the Principal and faculty of Shillong College, Shillong, Meghalaya for funding a workshop on capacity building in conservation of freshwater ecosystems in 2014 and the staff of St. Anthony's College for hosting Sonali Saha as a visiting faculty member in 2015.

Introduction

Northeastern India is a region blessed with plentiful rainfall, streams and rivers, and is also part of the Eastern Himalayan biodiversity hotspot (Allen et al 2010). However, changing land use, growing water demands and pollution are rapidly altering water quality and quantity, and in the process destroying the diversity of life in the streams, rivers, lakes and wetlands in the Indian Northeast and tropical Asia in general (Dudgeon 2011, Massar and Saha 2016). There is very little information on freshwater aquatic ecosystem communities in the Northeast, or how these ecosystems are linked/maintained with water flow, quality, stream bank vegetation and watershed land use. Furthermore, there is very little public awareness of precisely how healthy aquatic ecosystems help maintain water quality in streams. As an initial means of addressing the lack of information, biomonitoring programs were developed in 2014 in several colleges in Shillong, Meghalaya in order to survey and monitor aquatic fauna, specifically macroinvertebrates of Meghalayan streams along with hydrological data. The programs were also conceived as a way to develop capacity of college students in the field of freshwater ecology and conservation. This article presents biomonitoring data from sampling conducted by undergraduate students and their supervising faculty from colleges of Shillong.

The role of aquatic macroinvertebrates in maintaining ecosystems

Aquatic macroinvertebrate assemblages comprise primarily of insect larvae that have terrestrial adult life forms, insects whose adult life-history stages such as beetles and true bugs are also aquatic, and include arthropods such as crustaceans, and organisms from other phyla such as mollusks (gastropods, bivalves), and annelids (*Oligochaete, Hirudinea*; Allan 1995, Meritt et al. 2008). Benthic macroinvertebrates are an important part of the food chain, especially for fish and other predators. Macroinvertebrates occupy different trophic levels in a food chain due to diverse feeding habits; many feed on algae and bacteria, some eat leaves and other organic matter, some are filter-feeders and quite a few are predatory on other insect larvae, crustaceans and small fish. Because of their abundance and intermediate position in the aquatic food chain, benthic macroinvertebrates play a critical role in the natural flow of energy and nutrients (Resh et al. 1995), including assisting in breakdown of leaf litter and organic matter decomposition.

Macroinvertebrates: links with water quality

Macroinvertebrate assemblages show a strong correlation with variables of water quality and stream geomorphology (Resh et al. 1995, Lamouroux et al. 2004). In particular, the larvae of mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*) and caddisflies (*Tricoptera*), or EPT taxa as they are collectively known, are globally associated with clear swift-flowing streams where they shelter underneath stones on the streambed, the sedimentation of which can thereby remove their habitat. Clear headwater streams are typically cool and highly oxygenated, especially in riffle sections. The EPT taxa larvae are more susceptible to the physical or chemical changes associated with pollution and siltation in a stream than other organisms. Thus, the presence of EPT insect larvae indicates the maintenance of the natural flow and water quality regimes, that in turn indicates a healthy catchment with regulated hydrology and lack of significant soil erosion and other forms of anthropogenic pollution. Pollution sensitive organisms act as indicators of the absence of pollutants. Pollution-tolerant organisms such as midges and worms are less susceptible to changes in physical and chemical parameters in a stream and their presence is an indirect measure of pollution. When a stream becomes polluted, pollution-sensitive organisms decrease in number or disappear; pollution-tolerant organisms increase in variety and number. Thus the maintenance of macroinvertebrate biodiversity is a critical test of whether the water use regime is sustainable (Dudgeon et al. 2004).

Biomonitoring of aquatic ecosystems – a holistic assessment of watershed ecosystem condition

Biological measures provide an integrative measure of stream health over space and time, as opposed to snapshots of stream conditions as obtained by physicochemical parameters (Karr 1999). The lack of effective soil conservation in farming, mining and roadbuilding all accelerate soil erosion with sediment being washed off into streams and rivers. The resulting siltation of streambeds covers rocks and thereby removes habitat for the aquatic larvae sheltering underneath rocks from the swift flowing currents (Feio et al. 2015). Alterations in the streamflow regime can also affect both the breeding and dispersal of invertebrates, as well as alter water quality, in particular, lower dissolved oxygen below the levels that swift-flowing stream fauna are used to (Williams 1996, Mesa 2012).

Biomonitoring of freshwater ecosystems using aquatic macroinvertebrate abundance and diversity is thus a widely used tool to assess the health of aquatic ecosystems and to determine policy intervention with regards to developing and enforcing regulation for water quality (Bonada et al. 2006, Kennedy et al. 2009). Biological stream monitoring is based on the fact that different species react to pollution in different ways. Biomonitoring also adds the possibility of encountering new species that are not known to science and can enhance the understanding of life history traits of macroinvertebrates. As a consequence of all these benefits, biomonitoring is being mainstreamed into policy regulations for managing water quality in streams and rivers.

Biomonitoring as a tool for building capacity in society

Documentation of stream and river conditions using aquatic macroinvertebrates is an appropriate tool to develop capacity in the field of freshwater ecosystem science and conservation (Goulden 2009), especially in region rich in springs, streams, and aquatic biodiversity such as Meghalaya. However, it has never been put in practice before in this region. This pioneering hands-on experience brings students in close contact with the ecosystem. Periodic monitoring develops an appreciation for the links between a diverse ecosystem and the physico-chemical parameters of water quality and flow that maintain life. Biomonitoring of streams and rivers enables students to relate river parameters such as water depth and discharge to the daily availability of water as well as with extreme events such as floods and droughts. By correlating the diversity and abundance of freshwater taxa with water quality and quantity, baseline ecohydrology information on streams and rivers can be obtained; rivers harboring healthy and diverse ecosystems would be considered reference sites as benchmark for restoration. Thus biomonitoring enhances the understanding of rivers as living parts of the landscape, which needs ecologically-guided maintenance and protection, and not just as a natural resource to be harvested. In this article we summarize results from biomonitoring projects that have been undertaken since 2014 by different colleges in Meghalaya.

Study Site and Methods

Creating a capacity building network

This study was conducted by the members of a biomonitoring network which was established in 2014

as a part of capacity building program in Meghalaya to develop baseline data on hydrological parameters and macroinvertebrate diversity in streams and rivers with the help of undergraduate college students and their advisors. In a 10-day workshop held in July 2014, students were introduced to the tools of scientific method and research in the field of freshwater ecology and conservation. Field trips were organized where students learned the methods of biomonitoring and measuring water quality and hydrological parameters with the experts in the field. We had a total of 70 students participating with eighteen faculty members. The entire group was divided into subgroups supervised by 1 or 2 faculty members. Each subgroup learned and independently conducted measurements of different parameters. A total of six colleges from Shillong were part of the network, with each college with the team of 10-15 students and two faculty members. Each participating college chose a stream to monitor based on convenience of access and selected a sampling regime that was contingent on funds and time at the team's disposal. Table 1 lists the streams, sampling regime, site location, and parameters measured while Figure 1 shows the locations in Meghalaya where stream biomonitoring was conducted by students representing six colleges of Shillong.

Meghalaya is a state in Northeast India with annual rainfall averaging to 1150 cm; it is an extremely wet place, with the world's highest rainfall occurring at Cherrapunjee-Mawsynram (Basumatary et al. 2013), but with increasing water shortages in the dry season. Topographically Meghalaya is a plateau peaking at the altitude of 1964 m. The catchment divide is oriented in an east-west direction bisecting the state so that the north facing slopes drain into the Brahmaputra river, while the sharply incised southern slopes rapidly drain into Bangladesh to join the Barak-Meghna river system. Sites were chosen on both northern and southern sides of the topographic divide in Meghalaya (Table 1, Figure 1) across a variety of land use patterns in the catchment resulting in varying degrees of habitat impairment and pollution. Both temporally intensive (year-long study) and spatially extensive (spot sampling) regimes of sampling were conducted.

The temporally intensive study consisted of a year-long monthly sampling of two streams - Umkaliar (in Shillong, polluted) and Lwai (22 km from Shillong, unpolluted). This study was conducted by Shillong College from October 2014 to September 2015. Umkaliar, stream drains the Shillong urban area and thus is subject to pollution from domestic and municipal greywater discharge, solid waste, construction site debris, car washing, small industrial pollution and stormwater runoff carrying oils and grease from roads. Lwai on the other hand is much less polluted, as the catchment is largely a mix of terraced agriculture and forests, although increasing farming has the potential for sedimentation and agrochemicals.

The spatially extensive study consisted of a one-time or bi-annual spot sampling of Lawjynriew, Malki, Mawshubuitin, Umshyrpi and Wahdienglieng streams located in and around Shillong urban area (25º32′10″ N to 25º36′20″ N latitude and 91º51′30″ to 91º51′30″ E longitude) during the monsoonal rains (May to September in Meghalaya) and in the winter (December-February). In addition, two sites on the northern side of the divide were on streams of the Umran river draining the foothills in Ri Bhoi district near Umsning Village (25º44′1.2″ N latitude and 91º51′35″ E longitude) amidst mixed agriculture and forest. Three sites were on the southern flanks of the topographic divide near Lapalang village on the Rymben river in East Khasi Hills District, about 60 km southeast of Shillong. The Rymben is a fast flowing river with pools and riffles draining the southern flanks of the East Khasi Hills very close to the border with Bangladesh. The catchment is dominated by mixed agriculture in valley bottoms, cultivation of broomgrass and betelnut, with native evergreen forests remaining on steep slopes. Spot sampling was conducted by colleges that had limited resources and time to dedicate for fieldwork. Spot sampling enabled observing the spatial variation in water quality, hydrology, and biotic index, even though this was done once or twice. Multiple sections separated by at least 2 km and belonging to different stream orders of Umshyrpi and Umran river network were sampled. Table 2 lists the dominant riparian vegetation present along each of the stream courses (although it was beyond the scope of the study to assess percent cover of riparian vegetation).

Biomonitoring using benthic macroinvertebrates

Macroinvertebrates were collected from shallow riffle habitats in streams that students could access. Three stream reaches 50 m apart were chosen for sampling per stream site. Macroinvertebrates were collected by flushing organisms from under the rocks, floor of the channel and debris and were collected in a net held just below or downstream of the sample area. Wood, stones and debris collected from the net was sorted for macroinvertebrates and the samples pre-

Table 1 : Stream biomonitoring conducted by students from different colleges in Meghalaya.
*For these streams two distinct lower order streams from their catchment network were chosen for sampling.
DO (Dissolved Oxygen).

Stream/river	Location	Sampling regime	Sampling performed	Parameters sampled	Hydrological variables
Lwai	25°27′59.1"N 91°56′04.5"E	Monthly	Sep 2014-2015	Macroinvertebrates DO, turbidity, nitrates, TDS	None
Lawjynriew	25°33′30.1"N 91°54′08.2"E	One-time	Oct 2014	Macroinvertebrates DO, turbidity	Discharge
Malki	25°33′21.3"N 91°53′27.4"E	One-time	Oct 2014	Macroinvertebrates DO, turbidity	Discharge
Mawshubuit	25°33′21.8"N 91°53′27.4"E	One-time	Oct 2014	Macroinvertebrates DO, turbidity	Discharge
Rymben	25°11′34.8"N 91°57′29"E	One-time	Nov 2015	Macroinvertebrates, DO, turbidity	Discharge
Umran* (2^{nd} and 4^{th} order streams)	25°33′21.8"N 91°53′27"E	One-time	August 2014	Macroinvertebrates DO, turbidity	Discharge
Umkaliar	25°34′44.4"N 91°54′24.4"E	Monthly	Sep 2014-2015	Macroinvertebrates DO, turbidity, nitrates, TDS	None
Umshyrpi*, 1^{st} order 3^{rd} order streams	25°33′11.9"N 91°52′09.8"E 25°33′07.9"N 91°51′42.6"E	Bi-yearly	Oct-Dec 2014	Macroinvertebrates, DO, turbidity, pH	Discharge
Wahdienglieng	25°33′34.4"N 91°53′42.2"E	One-time	Oct 2014 Jan 2015	Macroinvertebrates DO, turbidity, pH	None

served (in 70% ethyl alcohol). Pools are the other main type of physical stream habitat but do not contain the abundance and diversity of macroinvertebrate fauna found in riffles (however, being deeper and having calmer water, pools constitute the preferred habitat for the larger stream fish such as trout and mahseer). This collection contains aquatic invertebrates in proportion to their relative abundance within the riffle sample areas. Samples were identified up to the order level and in some cases up to the family level.

To assess the stream conditions, a scoring process was used to derive metric value that relies on macroinvertebrate abundance and diversity data (Sharpe et al. 2002). Grossly polluted streams have scores ranging from 0-2, moderately polluted streams range from 3-9, and clean streams have value of 10. The index value is obtained by allocating a higher score to the species richness of pollution sensitive taxa belonging to the insect orders *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies) and *Trichoptera* (caddisflies, excluding the net spinning caddisfly), a lower score to richness of taxa belonging to insect

Table 2. Description of riparian vegetation bordering the sampled streams.

Stream	Vegetation
Lwai	Riparian vegetation included understorey tree of *Litsea* spp., and shrubs belonging to genera *Ardisia, Psychotria, Pittosporum,* and tree fern *Cyathea gigantea*
Lawjynriew	Riparian zone was dominated by shrubs-*Mahonia pycnophylla, Daphne papyraceae, Polygala arillata, Camellia caduca, Rubus* spp., and herbs belonging to families Balsaminaceae and Asteraceae
Malki	Riparian plants were shrubs- *Mahonia pycnophylla, Daphne papyraceae, Polygala arillata, Camellia caduca, Rubus* spp., and herbs belonging to families Balsaminaceae and Asteraceae
Mawshubuit	*Mahonia pycnophylla, Daphne papyraceae, Polygala arillata, Camellia caduca, Rubus* spp., and herbs belonging to families Balsaminaceae and Asteraceae
Rymben	The riparian vegetation consists of steep slopes lining the perennial river which has mid-sized trees of *Syzygium* spp., *Tetrameles nudiflora* and shrubs such as *Dracaena elliptica, Leea edgeworthia,* while plantations of *Areca catechu* mixed with species of *Artocarpus, Cinnamomum* and *Bauhinia* occur on gentle slopes.
Umran* *(2nd and 4th* order streams)	In the first order stream the riparian vegetation consisted of *Ardisia* spp., *Dracaena elliptica, Leea edgeworthia, Phlogacanthus* sp., and other species belonging to the family Acanthaceae, Rubiaceae, Balsaminaceae and Asteraceae. The third order stream dominated by dense grassy vegetation including broom grass *Thysanolaena* maxima and woody taxa such as *Syzygium* and *Leea.*
Umkaliar	Trees belonging to *Litsea* spp., and shrubs belonging to genera *Ardisia, Psychotria, Pittosporum,* and tree fern *Cyatheae*
Umshyrpi*, 1st order and 3rd order streams	1st order stream had the shrubs *Lasianthus hookerii, Ardisia* sp. and herbs such as *Costus* sp. The bank of 3rd order stream was impacted by human activities. It had trees of *Syzygium* sp., and *Melocanna* bamboo clumps and other grass taxa.
Wahdienglieng	Trees of *Syzygium* sp., *Litsea* sp. *Ficus* sp., grass taxa and human settlements

orders *Odonata*, *Megaloptera*, some Coleopterans, and crustacean orders, *Isoptera* and *Amphipoda*, while the pollution tolerant taxa are not scored at all. Pollution tolerant taxa are Dipteran (true flies) larvae, adult aquatic Coleopterans (beetles), Mollusca order *Gastropoda* (snails) and aquatic earthworms, *Oligochaeta*, Hemipterans and surface film insects.

Biotic Index was calculated as

Biotic Index = 2(n Class I) + (n Class II)

where n = number of taxa (species richness per category of taxa)

Pollution sensitive taxa belong to Class I while moderately sensitive taxa belong to Class II. Pollution tolerant taxa belonging to Class III are not considered in the calculation of Biotic Index. Samples were identified using a pictorial field guide (Subramaniam and Sivaramakrishnan 2007) to key taxa up to the family level when possible.

Hydrological, physical and chemical parameters

Concurrent measurement of river discharge, dissolved oxygen, pH, temperature and turbidity were made. To measure stream discharge, stream velocity was obtained using the classic float method (tennis

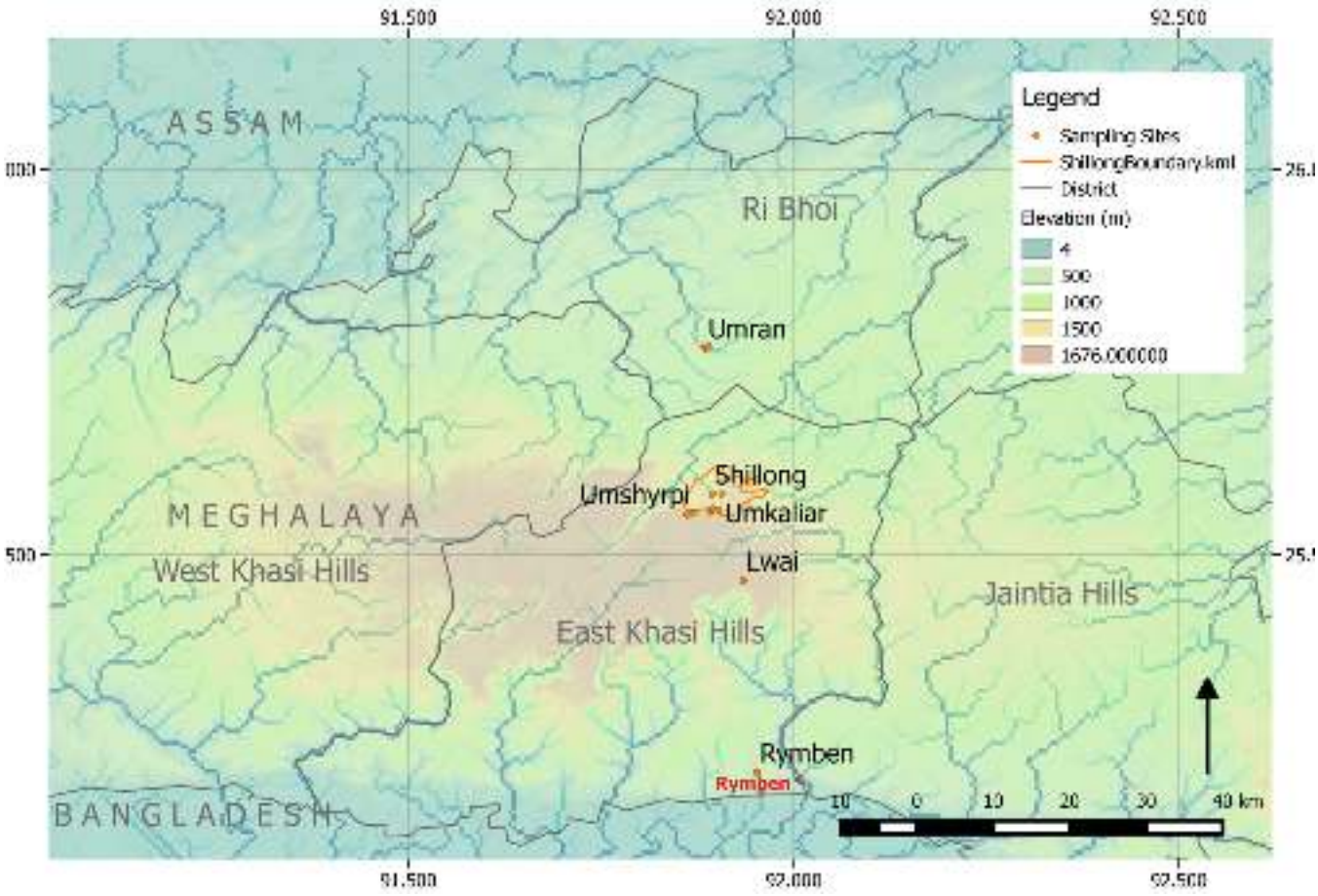


Figure 1 : Study site groups (Umran, Shillong and Rymben) represented by orange dots in Ri Bhoi and East Khasi Hills Districts in Meghalaya. Shillong urban boundary is delineated by the orange line. Map generated by drainage network delineation using QGIS upon ASTER 30 m Digital Elevation Model. Umkaliar is within Shillong city while Lwai stream is further away from the city or any other larger towns

Figure 2 : Students measuring discharge and collecting macroinvertebrates in the 2nd and 4th order streams of Umran river near Umsning village, Ri Bhoi District, Meghalaya.

ball) or mechanical current meter (General Oceanics 2030R, Miami, USA) and multiplied by stream cross sectional area (average channel depth*channel width). Dissolved oxygen (DO) was measured using a hand held portable dissolved oxygen meter (Milwaukee MW600, Milwaukee Instruments, North Carolina, USA).

Turbidity measurements were made with a turbidity tube (Meyer and Shawn 2006). The turbidity tube uses the correlation between visibility and turbidity to approximate a turbidity level. A marker is placed at the bottom of the turbidity tube until it can no longer be seen from above due to the murkiness of the water. This height from which the marker can no longer be seen correlates to a known turbidity value which is reported in Nephelometric Turbidity Units (NTU). Cloudier the water, higher is the turbidity value.

Results

Biomonitoring Network: A capacity building initiative

The biomonitoring network consisting of institutions from Shillong conducted stream surveys and monitoring of hydrological and water quality parameters. The colleges that participated in the network and sampled selected streams (stream names in parentheses) were: Lady Keane College (Umran), Shillong College (Lwai, Umkaliar, Umran streams), Sankardev College (Umshyrpi river), St. Anthony's College (Wahdienglieng), St. Mary's College (Umran), Synod College (Umran), and Umshyrpi College (Umshyrpi). Besides academic institutions three independent researchers from Shillong with Master's degree in Ecology also participated and shared their data (Lawjynriew, Malki, Mawshubuit). Equipment were provided to the network participants and in some cases the colleges purchased the equipment for sampling. This is the first time such a data set is being presented and analyzed to understand emerging trends in the region.

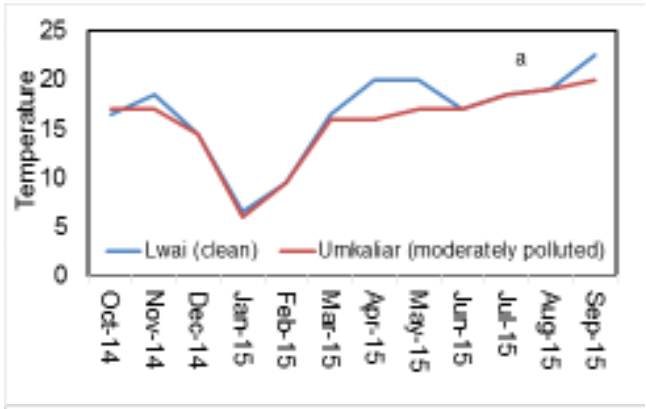
Year-long study: Trends from Umkaliar and Lwai streams

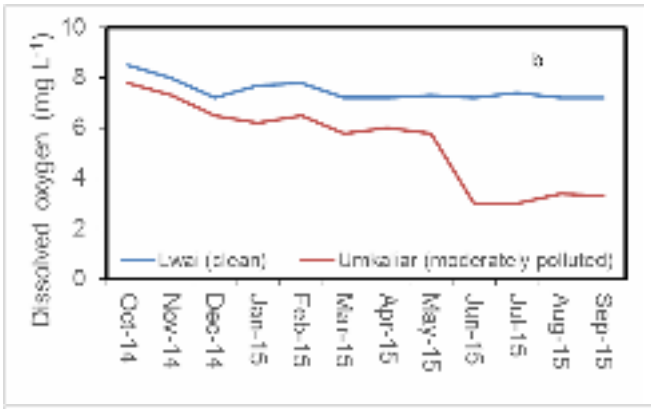
Water Quality

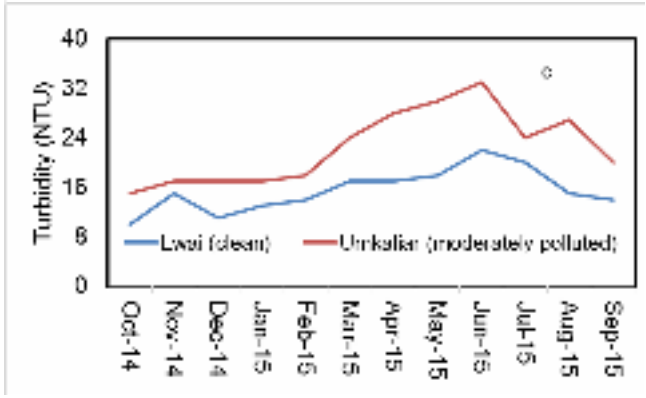
Data taken monthly from Umkaliar and Lwai

Table 3 : Summary table showing mean values of the measured water quality and hydrology parameters collected from year-long and spot sampling.

Stream/river	Mean DO mg L^{-1}	Mean Turbidity NTU	Mean Biotic Index	Mean Discharge m^3/s
Lwai	7.5	15.5	14.6	Not collected
Lawjynriew	7.3	5	18	0.001
Malki	8.6	45	10	0.025
Mawshubuit	12.5	4	18	0.008
Rymben	8.7	4	12	2.53
Umran* (2nd and 4th order streams)	12.2 12	4 7	16 9	0.030 2.83
Umkaliar	5.7	22.6	8	Not collected
Umshyrpi*, 1st order 3rd order streams	12 6.8	15 90	14.5 8	0.025 0.62
Wahdienglieng	8.4	40	12	0.028







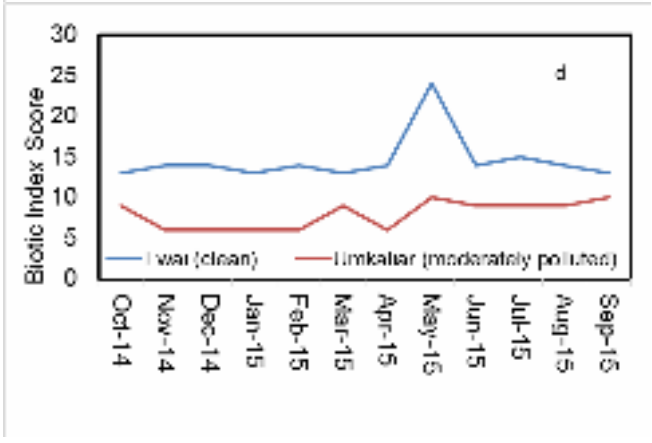


Figure 3 : Pictures of Umkaliar and Lwai streams followed by data graphs.
a : Temperature variation across months, Lwai stream was marginally warmer than Umkaliar stream. b : Trend in dissolved oxygen at Lwai and Umkaliar streams over a sampling period of one year, DO at Lwai was significantly higher than Umkaliar. The trend in relation to temperature is sharper for the polluted stream compared to clean Lwai stream. c : Turbidity was significantly higher in Umkaliar than Lwai stream. d : Biotic index scores based on sampling of macroinvertebrates from the riffle sections of the streams. Biotic index values obtained at Lwai, indicate that the stream is fairly clean.

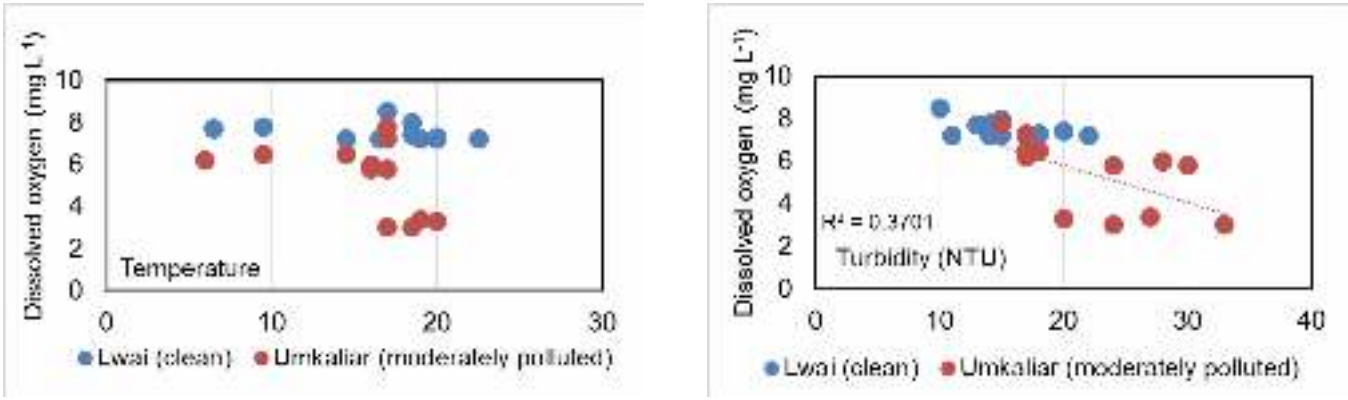


Figure 4 : Left panel shows a non-significant decline in DO in relation to stream temperature in moderately polluted stream, while in Lwai stream DO stayed stable across the year. Right panel also depicts that turbidity explains a significant trend in DO values in moderately polluted stream, while in Lwai stream the pattern is non-significant.

streams showed seasonal trends in temperature and dissolved oxygen (DO). DO values increased with decrease in water temperature accompanying the onset of winter. Seasonal difference in DO was greater in the polluted Umkaliar stream (average of 5.7 ± 0.92 mg L-1 Figure 3 upper panel) as compared to Lwai, because summer DO values in the Umkaliar dropped much lower.

A set of paired t-tests were used to compare the differences in monthly DO, temperature and turbidity between the two streams. Temperature in Lwai stream was marginally higher than Umkaliar stream across the entire year ($t = 2.1$, $df = 11$, $P = 0.05$, with mean of 16.8 0C at Lwai and 15.4 0C at Umkaliar; Figure 3a). The temperature difference could be due to the higher altitude and temperate climate of Umkaliar stream as compared to Lwai stream that is in sub-tropical habitat. Dissolved oxygen at each monthly sampling event was significantly higher in Lwai compared to Umkaliar stream ($t = 4.46$, $df = 11$, $P < 0.001$, with mean of 7.6 mg L-1 at Lwai and 5.7 mg L- at Umkaliar; Figure 3b). Turbidity values were significantly higher in Umkaliar stream than Lwai strean ($t = 4.89$, $df = 11$, $P < 0.001$, with mean values of 22.6 NTU at Umkaliar and 15.5 NTU at Lwai and; Figure 3c). Turbidity did not show a specific seasonal pattern. Since biotic index is a derived variable we did not perform a paired t-test. Results of water quality parameters are summarized in Table 3 for both Lwai and Umkaliar streams.

Variations in dissolved oxygen and turbidity were not explained by temperature (Figure 4 upper panel). Turbidity however had a marginally significant effect on dissolved oxygen and explained variation in DO values ($P = 0.05$, $R2 = 0.37$; Figure 4 lower panel).

Biotic index

Lwai stream had a higher biotic index with an average of 14.6 ± 0.8 (mean ± SE; Figure 3d) which is an indication of clean streams, as compared to Umkaliar stream where the average biotic index score was 8 ± 1.4 indicating a moderately polluted stream. Lwai harbored a higher diversity of pollution sensitive taxa - caddisflies, stoneflies, mayflies, adult water beetles, water scorpions and snails were commonly found (Table 2). On the other hand, leeches, mosquito larvae, midge larvae, snails, and mayflies were frequently encountered in the Umkaliar stream. No seasonal trends in biotic index were observed in Lwai or Umkaliar streams. The only high index value was observed for May 2015 at Lwai stream. No significant effect of seasonality were found on biotic index score for both the Lwai and Umkaliar streams.

Spot sampling in 8 streams: spatial inferences

The dataset from 8 streams sampled (Table 1) were pooled to examine if there was spatial variation in biotic index, turbidity, temperature and discharge in the region. Table 3 provides a summary of results from all streams included to represent spot sampling regime.

Stream discharge:

Seasonal discharge varied among sites as a factor of channel width and stream morphology. Most 1st and 2nd order streams showed lower and comparable discharge values while the larger 3rd and 4th order streams showed higher discharge values owing to larger channel widths.

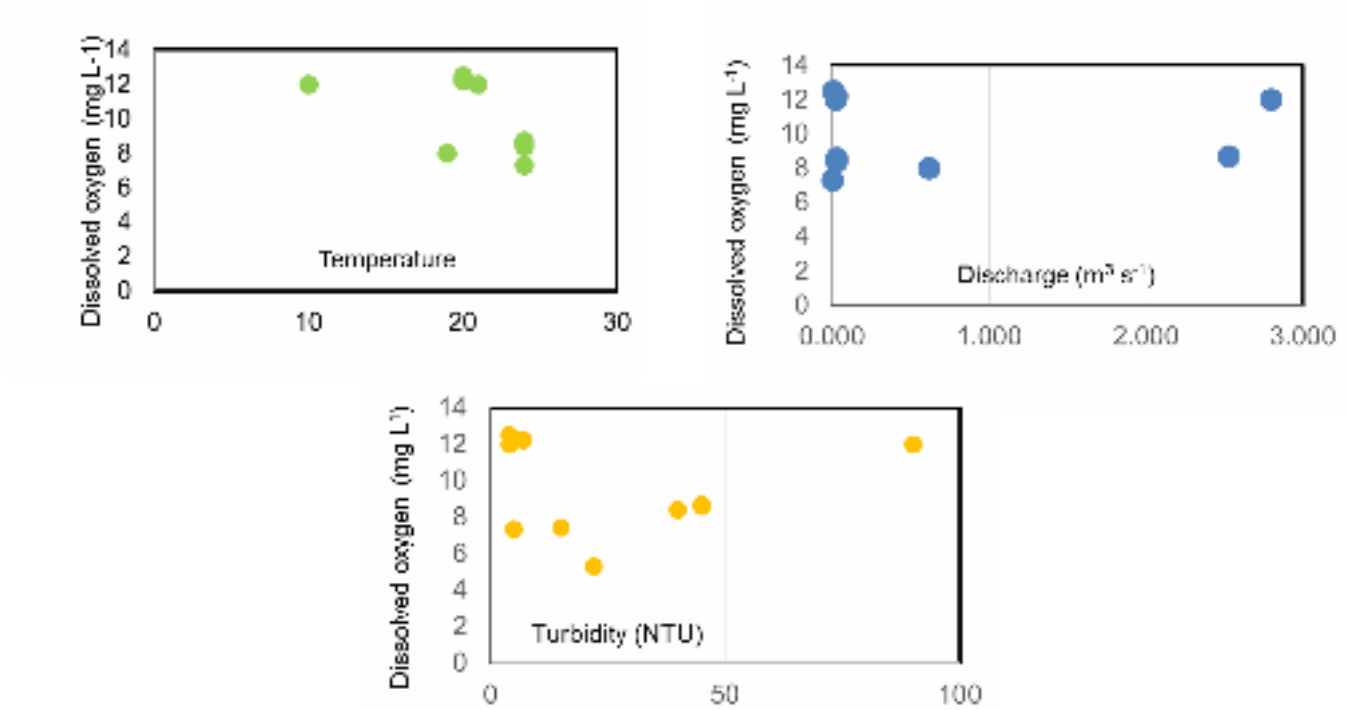


Figure 5 : Spatial variation in relationship between DO and the variables- temperature, turbidity, and discharge. Upper left panel depicts a DO against temperature across the entire spectrum of streams sampled in Shillong; Upper right panel shows that discharge can be categorized as low values within 1st and 2nd order streams, intermediate value for 3rd order stream and highest for 4th order stream. Lower panel depicts the values of DO across a range of turbidity among the sampled streams.

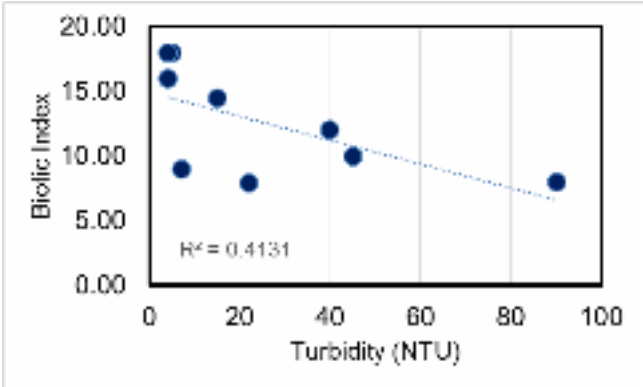


Figure 6 : Plot of biotic index against turbidity in spot sampling of 8 streams in Meghalaya. Increase in turbidity resulted in a significant decline of biotic index which is an indicator of macroinvertebrate diversity and abundance among pollution sensitive taxa.

Water quality

Dissolved oxygen values showed a non-significant decline with increase in water temperature (Figure 5 upper panel). Cooler waters have greater capacity to hold dissolved oxygen as compared to warmer waters, but the results were not significant.

No significant relationship was observed between discharge and dissolved oxygen concentration (Figure 5 middle panel) possibly because these were all fast-flowing streams that differed in discharge owing to channel width and not flow velocity. While higher DO values result from higher flow velocities on account of oxygenation of water from air entrapment, all streams

Figure 7 : Some specimens of macroinvertebrate larvae encountered in Meghalaya streams :

Top row, left to right : Water scorpion of Ranatra sp. (Family Nepidae, Order- Hemiptera), Mayfly larva of Family Heptageniidae, (Order- Ephemeroptera), damsel fly larva of Family Coenagrionidae (Order Odonata).

2nd row from top, left to right : Caddisfly larvae of Family Polycentropodidae (Order Trichoptera), Rove beetle of Family Staphylinidae (Order Coleoptera) -- not strictly aquatic but hunt along margins of water bodies), Caddisfly larva of Family Rhyacophilidae (Order Trichoptera), Amphipod (Order Amphipoda, Subphylum Crustacea), Caddisfly larva of Family Stenopsychidae, (Order Trichoptera),

3rd row from top, left to right : Dragonfly larva of Family Corduliidae (Order Odonata), Stonefly larva of Order Plecoptera and Crab (Crustacea) of Genus Liotelphusa, family Gecarcinucidae.

Table 4 : Common macroinvertebrates sampled from the riffle sections of streams in Meghalaya

Stream/river	Location	Sampling regime	Macroinvertebrates
Lwai	East Khasi Hills	Monthly, Sep 2014-2015	Caddisflies, stoneflies, mayflies, adult water beetles, water scorpion, mosquito larvae, snails
Lawjynriew	East Khasi Hills	One-time, Oct-2014	Caddisflies, stoneflies, mayflies, hellgrammite, dragonfly, water scorpion, midge larvae
Malki	East Khasi Hills	One-time, Oct-2014	Caddisflies, stoneflies, mayflies, dragonfly, adult water beetles, water scorpion
Mawshubuit	East Khasi Hills	One-time, Oct-2014	Caddisflies, stoneflies, mayflies, midge larvae, mosquito larvae
Umran 2nd order	Ri-Bhoi	One-time, July-14, Jan-14	Caddisflies, stoneflies, mayflies, dragonfly, adult water beetles, water scorpion, crabs
Umran 4th order	Ri-Bhoi	One-time, July-14, Jan-14	Caddisflies, mayflies, adult water beetles, aquatic earthworms
Umkaliar	East Khasi Hills	Monthly, Sep 2014-2015	Leech, mosquito larvae, midge larvae, snails, mayflies
Umshyrpi 1st order	East Khasi Hills	Once Oct-14	Caddisflies, stoneflies, mayflies, amphipod, adult water beetles, aquatic earthworms, snails
Umshyrpi 3rd order	East Khasi Hills	Once Oct-14	Adult water beetles, blackfly and midge larvae, aquatic worms, snails
Wahdienglieng	East Khasi Hills	Bi-yearly, Oct-14, Jan-15	Blackflies, caddisflies, mayflies, midge larvae

had high flows with possibly maximum oxygenation. Biochemical Oxygen Demand (BOD) also affects DO; however measuring BOD of different streams was beyond the scope of the study.

Turbidity did not influence dissolved oxygen concentration (Figure 5 lower panel). Oxygenation of streams from turbulent flow can alleviate the negative impact of high turbidity on DO.

Macroinvertebrates

Biotic Index value across sites was negatively influenced by turbidity indicating that streams with lesser richness and lesser abundance of pollution sensitive taxa tend to have murky waters ($P < 0.001$, $r2 = 0.38$; Figure 6). Neither the index values nor the turbidity were influenced by temperature, thus the seasonality did not have confounding effects on the underlying pattern. Clearwater streams were found to have a higher Biotic Index, as determined by the occurrence of pollution-sensitive EPT taxa (mayfly, stonefly and caddisfly larvae). Interestingly, our limited sampling shows that the Biotic Index values are not influenced by dissolved oxygen in Meghalayan hill streams. A likely reason is that majority of streams are fast running owing to the high rainfall and steep topographic gradients, which increases oxygenation and can potentially offset the high BOD resulting from dumping of organic waste especially within the streams flowing

through Shillong. Figure 7 shows some of the invertebrates encountered in sampling. Table 4 summarizes the taxonomic groups (insect orders) observed at different stream locations. Studies in Meghalayan streams have reported 17 Ephemeropteran taxa across a diversity of stream habitats and land use (Gupta and Michael 1992). It is also known that macroinvertebrates are aseasonal in their activity. While several important ecosystem services are provided by streams and rivers, the ecology and life-history traits of Ephemeropterans and aquatic macroinvertebrates in the tropics in general are poorly studied (Gupta 1993, Dudgeon 1999, Hamid et al. 2016).

Discussion

The biomonitoring initiative in Meghalaya was set up with a dual aim :

1. to infuse curiosity, to introduce students to the scientific method of asking and answering questions in stream ecology, and to establish in their minds the links between healthy aquatic ecosystems, water availability and quality;
2. to begin the process of documenting macroinvertebrate diversity in conjunction with hydrological and physico-chemical parameters of streams, so that eventually a metric for streams in Meghalaya can be established, which could be used state-wide.

While stream biomonitoring with benthic macroinvertebrates is a tool for guiding policy on setting effluent limits and water quality standards (Kennedy et al. 2009), capacity building in freshwater ecology is a novel application of biomonitoring. Several colleges from Shillong, Meghalaya, participated in designing the studies, collecting and analyzing data, the results of which were presented in international conferences (Saha 2016) and college seminars. While several studies have looked at diversity and abundance of macroinvertebrates as a biomonitoring tool in Indian streams and rivers (for example, Martin et al. 2000, Shah and Shah 2013), few studies exist in the Indian Northeast. Figures 3-7 provide a glance at some results from our work.

Comparing aquatic invertebrate assemblages in streams with contrasting water quality

The summer water temperature values were almost four times higher than mid-day winter water temperature. Dissolved oxygen showed a non-significant decline in summer months especially in the polluted Umkaliar stream while showing stable values in Lwai stream. Cooler water temperatures support greater DO levels than warmer temperatures (Michaud 1991, Wetzel 2001). We observed some low DO values in Umkaliar stream during summer season, when DO values were around 3 mg L-1.

Dissolved oxygen is the most important abiotic parameter that influences the health and composition of aquatic communities, macroinvertebrates and fish require a certain amount of dissolved oxygen to survive (Flint and Pearson 2015). Dissolved oxygen in the summer months, especially early summer after the rains set in is reported to be very low in Umkaliar because of flushing of raw sewage and organic waste from the surrounding and upstream areas leading to increasing biological oxygen demand and lowering in DO levels (Mnaya et al. 2006). The watershed land use of Umkaliar stream is influenced by a much higher level of anthropogenic activities as compared to the rural watershed of Lwai stream. Also the abundance of chironomidae midge larvae seemed to be exceptionally high during the early to mid-summer season in Umkaliar stream, which may have lowered DO concentration. The relationship between temperature and DO was not significant in Lwai stream as well perhaps because discharge (not measured here) is very high in summer monsoonal months, compensating for the effect of temperature.

Significant differences in turbidity and dissolved oxygen (DO) between the clean Lwai and polluted Umkaliar streams were reflected in distinct macroinvertebrate assemblages observed at each of the streams respectively. Lwai stream with clear water and year-round high DO levels supported pollution-sensitive macroinvertebrates such as stoneflies and mayflies (sensu Rosenberg and Resh 1993, Lamoureaux et al. 2004), while pollution tolerant taxa such as midge larvae and mosquito larvae were common in Umkaliar stream. The high turbidity and low DO concentration in Umkaliar stream was correlated with biotic index scores associated with moderately polluted streams (Sharpe et al. 2006, Feio et al. 2015).

Turbidity was significantly higher during all sampling events in polluted Umkaliar stream compared to Lwai stream. Turbidity is known to limit the ability of oxygen to freely dissolve in water (Hem 1985, Anderson 2005, Bayram et al. 2014, Smith 2015). Lower turbidity in Lwai compared to Umkaliar stream could have influenced DO values. It is also likely that Biological Oxygen Demand (BOD) in Umkaliar stream is higher than that in Lwai due to greater pollution (largely domestic wastewater) and intense anthropogenic use of Umkaliar stream. High levels of BOD

depress oxygen availability in waters as the processes involving decomposition and chemical reactions of organic matter tend to consume oxygen (Wetzel 2001). In Meghalaya, turbidity is generally caused by sedimentation resulting from deforestation and farming in steep slopes, eroding soil from the entire hilly areas especially in and around the city where hills are cleared for construction , practices such as washing of cars and trucks in the streams, and from dumping of sewage and solid wastes in the rivers which increases the murkiness and lowers the visibility in the streams.

Our data did not exhibit a strong seasonal variation in macroinvertebrate abundances; however patterns in adult emergence and life-history traits are known to influence the abundances of macroinvertebrates in monsoonal streams (Mesa 2012). An expansion of seasonal sampling across many other streams can give a better idea as to whether there are any seasonal differences in macroinvertebrate abundance and diversity in this part of Northeastern India.

Scaling up to the regional level

Our dataset on spatial variation in stream parameters on both sides of the topographic divide across central Meghalaya (spot sampling) allowed us to assess the range of water quality across sites and determine the effects of turbidity and DO on macroinvertebrate assemblages, even though these observations are from one or two points in time. Turbidity had a strong negative effect on macroinvertebrate assemblages as exhibited by decline in the biotic index score value with increase in turbidity. In an experimental study conducted in upland and lowland tropical Australian streams (Connolly et al. 2004), pollution sensitive macroinvertebrates show a depressed emergence rate in 25-30% saturation concentration of DO (4 mg L-1) while the larval abundances showed decline at 8% saturation concentration (around 2 mg L-1). Studies across taxa show that crustaceans and Chironomidae tolerate as low as 1 mg L-1 DO (Sprague 1968), while pollutions sensitive taxa need more than 5 mg L-l to avoid lethal consequences (Nebeker 1972). Most of the Meghalayan streams sampled here had relatively high DO values, with the exception of the Umkaliar stream draining urban Shillong where the DO values were as low as 3 mg L-l during the peak rainy season. The ability of fish to survive in low oxygen environments depends upon the extent of exposure, the level and constancy of dissolved oxygen and other environmental conditions, as well as on the species, its health, and life stage (Birtwell1989), which we do not have data on yet, but are working towards making our datasets stronger and comprehensive.

Biomonitoring as a way for capacity building: successes and challenges

While the studies have amassed interesting datasets in a short time on biotic and abiotic parameters of Meghalayan streams, our project was confronted by multiple challenges. A rapid turnover of students in an undergraduate college allowed us to train several groups of students over three years, but posed a logistical challenge to maintaining long-term studies. Similar to volunteer monitoring organizations that lack adequate technical support due to shortage of quality equipment (funding related) or inability of ground staff to troubleshoot technical problems (dearth of time, funding and experience), that hinder their ability to defend and interpret data on the quality of streams and lakes they monitor (Latimore and Steen 2014), our biomonitoring efforts face similar issues. Data collection efforts were interrupted due to equipment breakdown, lack of time among students and their supervising lecturers, and due to other higher priority activities such as semester and term exams. Yet, amidst these challenges, the colleges in Meghalaya have come forward and recognize that capacity building in the field of freshwater ecology opens up several novel horizons for college students and increases the ability of students and college staff to work for improving water quality in the region. Training in use of open source software and monitoring equipment, introduction to GIS, and data collection and analysis are some tools that are acquired by students working on biomonitoring projects. These tools increase employability of students in other sectors as well. Meghalaya's biomonitoring program now enters it's 3rd year of sampling with the hope that some of the older studies will be revived as newer studies are established.

Future directions

Apart from the benefits of biomonitoring programs in imparting a hands-on experience that creates a conservation mindset in the next generation, develops skills and adds baseline data on local ecosystems, such programs can be expanded to include examining the relationships between catchment land cover, riparian buffers or gallery forests and stream ecosystems. The role of riparian buffers in providing nutrient inputs and acting as filters that trap sediment from watershed runoff before entering streams is well known globally. It would be important to study that on a

watershed scale, so as to understand how to restore and manage riparian buffers to maintain water quality and aquatic ecosystems.

The hilly topography and abundant rainfall of Meghalaya leads to swift flowing rivers that are inherently well oxygenated, especially in the rainy season. However, large volume discharges of sewage and other high BOD wastes from urban areas can seriously lower DO levels in water. This DO reduction can be especially harmful in the dry season when flows are low. Apart from pollution via domestic and municipal sewage discharge, sedimentation from runoff from farming, road building, mining and deforestation can also wipe out sensitive invertebrates, with cascading effects upon other aquatic communities, thereby lowering ecosystem integrity and the services a healthy ecosystem provides in terms of clean water and fish resources. Hence, it is imperative to collect more data statewide on aquatic macroinvertebrates together with flow and water quality data from the same streams, and relate that to catchment land use. This data set can then be used to form a biomonitoring metric for Meghalaya, and extend to other hilly northeastern regions, as additional monitoring tools to existing physico-chemical monitoring, but one that gives an integrated picture over catchment and time.

Conclusion

Ultimately, clean adequate water and aquatic resources (such as fisheries) are necessary for all. Given the increasingly negative human impacts on aquatic ecosystems and their catchments, it is important for society to have a better understanding of the links between ecosystems and water resources, as well as to know how to monitor their local streams, thereby acting as sentinels for noticing adverse changes. The periodic monitoring of aquatic macroinvertebrates in streams indicates the health of the aquatic ecosystem as well as the surrounding catchment, and with that, the status of natural maintenance of water flow and quality. Monitoring, knowing what is the current status is the first step towards management of ecosystems and water resources that necessitates cooperation between all stakeholders involved, from local communities to the government, organizations and educational institutions. With that in mind, giving the current generation the tools and the perspectives is a way to foster a collective conservation mindset. The protection and wise management of natural resources requires our united effort, more than ever in recent history given the ongoing degradation and the looming uncertainty of climate change upon water resources.

References

Allan, J. D. 1995. Stream Ecology. Structure and function of running waters Chapman and Hall. Boston, Massachusetts, USA. 388 pp.

Allen, D.J, Daniel, B.A and Sanjay M. 2010. The Status and Diversity of Freshwater Biodiversity in the Eastern Himalaya. IUCN Red List of Threatened Species – Regional Assesment. Cambridge, UK and Gland, Switzerland. ISBN: 978-2-8317-1324-3

Anderson, C.W. 2004. Turbidity in National Field Manual for the Collection of Water-Quality Data (TWRI Book 9, chapter A7, section 6.7). U.S. Geological Survey. Accessed August 25, 2016 at http://water.usgs.gov/usgs/owq/6.7-online.pdf. Accessed August 28, 2016.

Basumatary, S.K., S. Dixit, S.K. Bera, S.K. and R. C. Mehrotra. 2013. Modern pollen assemblages of surface samples from Cherrapunjee and its adjoining areas, Meghalaya, northeast India. Quaternary International 298: 68-79

Bayram, A., H. Önsoy, M. Kankal, and M. I. Kömürcü. 2014. Spatial and temporal variation of suspended sediment concentration versus turbidity in the stream Harsit Watershed, NE Turkey. Arabian Journal of Geosciences 7: 4987-4996

Birtwell, I. K. 1989. Comments on the sensitivity of salmonids to reduced levels of dissolved oxygen and to pulp mill pollution in Neroutsos Inlet. Canadian Technical Report of Fisheries and Aquatic Sciences 1956. 27pp

Bonada , N. , N. Prat , V.H. Resh , and B. Statzner. 2006 . Developments in aquatic insect biomonitoring: A comparative analysis of recent approaches. Annual Review of Entomology 51: 495 - 523.

Connolly, N. M., M. R. Crossland and R. G. Pearson. (2004). Effect of low dissolved oxygen on survival, emergence, and drift of tropical stream macroinvertebrates. Journal of the North American Benthological Society 23: 251-270.

Dudgeon, David. 2011. Tropical stream ecology. Academic Press, 2011.

Dudgeon, D., A.H. Arthington, M. O. Gessner, Z. I. Kawabata, D. J. Knowler, C. Lévêque, R. J. Naiman, A. H. Prieur-Richard, D. Soto, M. L Stiassny, and C. A. Sullivan. 2006. Freshwater biodiversity : importance, threats, status and conservation challenges. Biological reviews, 81: 163-182.

Feio, M. J., W. R. Ferreira, D. R. Macedo, A. P. Eller, C. B. M Alves, J. S. França, and M. Callisto, 2015. Defining and testing targets for the recovery of

tropical streams based on macroinvertebrate communities and abiotic conditions. River Research and Applications, 31:70-84.

Flint, N., Crossland, M.R., Pearson, R.G. 2015. Sublethal effects of fluctuating hypoxia on juvenile tropical Australian freshwater fish. Marine and Freshwater Research 66: 293-304.

Gillain, S. 2005. Diel turbidity fluctuations in streams in Gwinnett County, Georgia. In, K.J. Hatcher (ed.), Proceedings of the 2005 Georgia Water Resources Conference, USGS. Accessed September 2, 2016 at http://ga.water.usgs.gov/publications/other/gwrc2005/

Giller, P. S. and B. Malmqvist. 1998. The Biology of Streams and Rivers. Oxford University Press, 304 pp.

Goulden, C.E. 2009. Capacity Building for Biomonitoring of Lakes and Streams. Accessed July 14, 2016 athttp://wldb.ilec.or.jp/data/ilec/WLC13_Papers/S6/s6-3.pdf.

Gupta, Abhik, and R. George Michael. 1992. Diversity, distribution, and seasonal abundance of Ephemeroptera in streams of Meghalaya State, India. Hydrobiologia 228. 131-139.

Gupta, Abhik. 1993. Life histories of two species of Baetis (Ephemeroptera: Baetidae) in a small North-East Indian Stream. Archiv für Hydrobiologie 127: 105-114.

Hamid SA, Rawi CSM, Ahmad AH. Life History of Thalerosphyrus (Ephemeroptera: Heptageniidae) in Tropical Rivers with Reference to the Varying Altitude. Tropical Life Sciences Research. 2016: 43-62.

Hem, J.D. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water, 3rd edition. USGS. Water-Supply Paper 2254.

Karr, J.R. 1999. Defning and measuring river health. Freshwater Biology 41: 221 - 234.

Kenney, M.A., A.E. Sutton-Grier, R.A. Smith, and S.E. Gresens. 2009. Benthic macroinvertebrates as indicators of water quality : The intersection of science and policy. Terrestrial Arthropod Reviews 2 : 99–128.

Lamouroux, N., S. Doledec, and S. Gayraud. 2004. Biological traits of stream macroinvertebrate communities: Effects of microhabitat, reach, and basin filter . Journal of the North American Benthological Society 2: 449 - 466.

Lamare R. E., and O. P. Singh. 2016. Seasonal Variation in Water Quality of Lukha River, Meghalaya, India. Current World Environment 11:101-113.

Latimore, J. A., and P. J. Steen Paul. 2014. Integrating Freshwater Science and Local Management through Volunteer Monitoring Partnerships : The Michigan Clean Water Corps. Freshwater Science 33: 686-92.

Massar, B., Saha, S. 2016. Fish diversity and catchment land-use of river Rymben in East Khasi Hills, Meghalaya. Pages 44-48 in Proceedings of the international conference on water resource management in the Eastern Himalayan region. Jyrwa, E., M. Pyngrope, S. Saha, B. Massar, (eds.). St. Anthony's College Publication, Mawsawa Press, Shillong, Meghalaya.

Martin, P., M. A. Haniffa, and M. Arunachalam. 2000. Abundance and diversity of macroinvertebrates and fish in the Tamiraparani river, South India. Hydrobiologia 430: 59-63.

Merritt, R.W., K.W. Cummins, and M.B. Berg. 2008. An Introduction to the Aquatic Insects of North America. 4th edition. Kendall Hunt Publishing. Dubuque, Iowa, U.S.A. 1158 pp.

Mesa, LM. 2012. Interannual and seasonal variability of macroinvertebrates in monsoonal climate streams. Brazilian Archives of Biology and Technology, 55: 403-410

Michaud, J.P. 1991. A Citizens' Guide to Understanding and Monitoring Lakes and Streams. Published by Washington State Department of Ecology Press. 73pp.

Miller, S. W., D. Wooster, D. and J. Li. 2007. Resistance and resilience of macroinvertebrates to irrigation water withdrawals. Freshwater Biology 52: 2494-2510.

Mnaya, B., Mwangomo, E., Wolanski, E. 2006. The influence of wetlands, decaying organic matter, and stirring by wildlife on the dissolved oxygen concentration in eutrophicated water holes in the Seronera River, Serengeti National Park, Tanzania. Wetlands Ecology and Management 14:421-425.

Mosley, L. M., B. Zammit, E. Leyden, T.M. Heneker, M.R. Hipsey, D. Skinner, and K. T. Aldridge. 2012. The impact of extreme low flows on the water quality of the Lower Murray River and Lakes (South Australia). Water Resources Management, 26: 3923-3946.

Myre, E. and R. Shaw. 2006. The Turbidity Tube : Simple and Accurate Measurement of Turbidity in the Field, CE 5993 Field Engineering in the Developing World and FW 5770 Community Planning and Analysis, Michigan Technological University, Houghton, pp. 3-4.

Nebeker, A. V. 1972. Effect of low oxygen concentration on survival and emergence of aquatic insects.

Transactions of the American Fisheries Society 4:675–679.
Rabha, B., S. Dhiman, K. Yadav, S. Hazarika, R.K. Bhola, and V. Veer. 2013. Influence of water physicochemical characteristics on Simuliidae (Diptera) prevalence in some streams of Meghalaya, India. Journal of Vector Borne Diseases 50: 18–23
Rosenberg, D. M., and V.H. Resh. 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman and Hall, New York, USA. 488 pp.
Saha, S. 2016. Capacity building in ecohydrology in Indian Northeast. Pages 77-82 in Proceedings of the international conference on water resource management in the Eastern Himalayan region. Jyrwa, E., M. Pyngrope, S. Saha, B. Massar, (eds.). St. Anthony's College Publication, Mawsawa Press, Shillong, Meghalaya.
Shah, R. D. T., and D. N. Shah. 2013. Evaluation of benthic macroinvertebrate assemblage for disturbance zonation in urban rivers using multivariate analysis: Implications for river management. Journal of Earth System Science, 122: 1125-1139.
Sharpe, W.E., W.G. Kimmel, and A. R. Buda, 2002. Biotic Index Guide. Pennsylvania State University,
Smith, D. 2015. Spatial and Temporal Variation in Water Quality along an Urban Stretch of the Chattahoochee River and Proctor Creek in Atlanta, GA. Thesis, Georgia State University, 408 pp Accessed August 23, 2016 at http://scholarworks.gsu.edu/iph_theses/
Sprague, J. B. 1963. Resistance of four freshwater crustaceans to lethal high temperature and low oxygen. Journal of the Fisheries Research Board of Canada 20:387–415.
Subramanian, K.A. and K. G. Sivaramakrishnan. 2007. Aquatic Insects of India-A Field Guide. Ashoka Trust for Ecology and Environment, Bangalore, India. 62pp.
van Vliet, M. T., W.H. Franssen, J.R. Yearsley, F. Ludwig, I. Haddeland, I., Lettenmaier, D. P. and P. Kabat. 2013. Global river discharge and water temperature under climate change. Global Environmental Change 23: 450-464.
Williams, D. D., 1996. Environmental constraints in temporary fresh waters and their consequences for the insect fauna. Journal of the North American Benthological Society 15:634–650.
Wetzel, R. G. 2001. Limnology : Lake and River Ecosystems, 3rd ed. San Diego, CA: Academic Press.

Non-palatable Medicinal Plants as a Solution to Crop Raiding by Wild Herbivores around Protected Areas

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Abstract

The Tadoba-Andhari Tiger Reserve (TATR) is an important nature conservation area for the country having a good population of wild animals. However, on the fringes of this national park, there are issues of human-wildlife conflict such as crop raiding by wild animals, which is an underestimated problem. The constant threat of crop predators and perceived loss in crop produce has discouraged agriculture in close vicinity of the park. Farming is the main livelihood for the people living near TATR, therefore it is an urgent need to keep under review the alternative options that can contribute to farmers' welfare. Considering the developing medicinal plant demand, there is potential in cultivating non-palatable traded medicinal plant species that are resistant to crop-raiding by wildlife. The paper suggests such a model for farmers. We focus on research, awareness, motivation, facilitation and establishing market linkages.

Introduction

Agriculture plays a vital role in India's economy. Over 58 per cent of the rural households depend on agriculture as their principal means of livelihood, our study area adjoining Tadoba Andhari Tiger Reserve (TATR) not being an exception. But at the same time, agricultural lands close to protected areas (PAs) often face crop raiding by wild herbivores, which is a serious problem for farmers whose livelihoods depend on agricultural produce (1,2,3,4). In order to avoid economic loss, farmers apply a range of protective measures. They include manual guarding, various types of fences, trenches and other devices. However, these measures often come with high associated costs and risks (5,6,7). The traditional fences are made using wooden poles and thorny branches lopped from nearby forests causing substantial damage to the forest. Destructive measures such as traps can kill or injure animals. Highly sophisticated means such as electric fences are expensive and need continued maintenance. Although a number of measures have been developed they seem to be failing at some or the other point of time (8). The traditional practices which generally keep raiding at bay and even culling are not advisable to avoid this conflict.

Compensating for loss is practised in India but the compensation amount given to victims is often inadequate (7,8) and hence management of wildlife is increasingly losing its harmony with local people (10). We still need to discover and implement ideas for fringe area management through various relevant means of livelihood which will positively contribute towards conservation. When we already know that management in such projects needs conservation with a focus on community participation, then changing their attitude toward it is of great significance. There is a positive link between the pertinent knowledge and attitudes to conservation (12,13,14). Consequently, it becomes self-evident to build interventions that raise awareness about conservation strategies. Strategies like medicinal plant based alternative liveli-

hood will amplify the knowledge and behavioural attitudes of the existing livelihood strategies (12).

The newly implemented restrictions on non-agricultural land use in the buffer area are likely to further worsen the conflict (22,25). The aim behind such restrictions is no doubt to promote coexistence between wildlife and human activity, with due recognition of livelihood, developmental, social and cultural rights of the local people. But now with many other options being cut off, alternative farm-based livelihoods need to be explored as a promising and workable option for these communities (1,4). Medicinal plants have the potential to contribute to output growth of agriculture in rural areas. Agriculture based additional livelihood generation will be important to achieve desirable quality of life for farmers. Executing such plantation of medicinal plants could intensify the introduction of simple new application-based technologies, which will have access to new markets (13, 16,17,18). For example, if farmers in such areas grow *Tulsi* plants, which is a non-palatable medicinal plant species, followed by a very simple value addition technique (i.e. drying) and with due training if they follow herbal infusion packing processes, it can directly contribute to their livelihood generation thanks to all the tourists visiting national parks who can become customers for such products.

Therefore, we felt that improving of existing livelihoods should be dealt in an innovative way. Considering the need for conservation and sustainability in the medicinal plants sector, a solution that combined both of these would be ideal. We initiated development of short-scale market strategies followed by training sessions for local people in this region. Diversification of such marketing strategies and their expansion at a larger scale was emphasized during the project period. Formation of a co-operative society of these communities can lead them towards fetching beneficial opportunities. They can achieve this through the National Medicinal Plant Board and other promotional schemes. Such livelihood creation, if linked to the co-operative groups will be a win-win model for local farmers.

Study area and relevance

Tadoba Andhari Tiger Reserve in Chandrapur district of Maharashtra state in central India is one of the 47 Project Tiger reserves in India. It is situated approximately 150 km south of Nagpur city. It was declared as a National Park in 1955. Tadoba National Park (116.55 Sq. Kms.) and Andhari wildlife sanctuary (508.85 Sq. Kms.) together form the Tadoba-Andhari Tiger Reserve. 625.82 sq.km. is the extent of the core area. In addition there is 1101.77 sq.km. of buffer area. The total legal area of the tiger reserve is 1727.59 km2. (Source: Website of NTCA).

There are over 79 villages in and around this tiger reserve. Villages along the western boundary of Tadoba Andhari Tiger Reserve, Chandrapur, Maharashtra including Ashta, Mudholi, Chandankheda, Vadala, Viloda were the focus of our study. The research site is shown in Figure 1.

The primary occupation for people in these fringe villages is agriculture. The agriculture is monsoon dependent. Although the rainfall is high, it is erratic and affects crop productivity. Under a traditional agricultural system composed of two separate seasons, namely *kharif* (monsoon crops) and *rabi* (winter crops), the following crops are grown here : Rice (*Oryza sativa*) and soybean (*Glycine max*) are the primary kharif crops whereas wheat (*Triticuma estivum*) and chickpea (*Cicerarie tinum*) are primary rabi crops. Apart from these, cotton (*Gossypium arboreum*), turmeric (*Curcuma longa*), flax or linseed (*Linum usitatissimum*), and grass pea or sweet blue pea (*Lathyrus sativa*) are other secondary crops taken to a lesser extent (8).

Figure 1 : Study Area

The study

Our current study is based on the background of a study conducted by a research team from IISER, Pune on crop raiding by wild animals along the western boundaries of TATR (9, 10).

The study comprised of four phases :

- Phase 1 : Selection of species
- Phase 2 : Trial plantation
- Phase 3 : Techniques for value addition and investment scenario
- Phase 4 : Market linkages

Phase 1 : Selection of species

Selection of species for propagation was done with the criteria of growth, minimum care, and non-palatable to herbivores. These species are as follows :

1. *Cymbopogon Sp.* (Citronella and Gavati chaha)
2. *Stevia rebaudiana* (Candy leaf/ Sweet leaf/Stevia)
3. *Andrographis paniculata* (Kalmegh)
4. *Asparagus racemosus* (Shatavari)
5. *Cassia angustifolia* (Sonamukhi)
6. *Withania somnifera* (Ashwagandha)
7. *Oscimum sanctum* (Tulsi)
8. *Cissus quadrangularis* (Hadjodi)
9. *Vetiveria zizanioides* (Vala)
10. *Acorus calamus* (Vekhand)

Phase 2 : Trial plantation of 10 species

We tried to grow selected medicinal plants which are in high trade in the study area to test their suitability for the soil and climatic conditions. Some of these can give yield year around and others with a short crop-like life cycle.

Table 1 : Economics of select plant crops

Name of crop	**Kalmegh**	**Tulsi**	**Vekhand**	**Stevia**
Type of crop	One time	Recurring	Recurring	Recurring
Harvesting cycle	7-9 months	Every 6 months for 3 years	Every year for 3 years	Every year for 5 years
Origin of planting stalk	Seeds	Seeds	Rhizome cuttings	Lower stem cuttings
Planting material	2000	500	32000	32500
Land Preparation cost	1200	1200	3000	1200
Weed Management	1500	3000	4000	6000
Sowing	1000	2000	2500	3500
Fertilizer	4000	5000	6000	6000
Harvesting	3000	5000	6000	3000
Post harvest Management	1500	2000	3000	8000
Total cost (Rs/acre)	**14,000**	**18,700**	**56,500**	**60,200**
Market rate/kg Year -2015-16	40	35	70	100
Yield per acre (according to standardized NMPB norms)	700 kg	1500–2000 kg	1000-1500 kg	1200 kg
Total income (Rs/acre)	**28,000**	**52500**	**70,000**	**1,20,000**
Economic benefit (Rs/acre)	**14,000**	**33,800**	**13,500**	**59,800**

Phase 3 : Techniques for value addition and investment scenario

In the trial plantation phase, some crops showed luxurious growth in the given experimental plots suggesting the suitability of that crop as a viable alternative. We could standardise the return on investment for these crop options. e.g. Kalmegh, Vekhand, Tulsi and Stevia.

Based on the data collected, the economics of these select species is given in Table 1 – all costs are in Rupees.

With further experimentation, we hope to finalise investment and return for other species like Citronella, Sonamukhi, Ashwagandha, Hadjodi and Vala, as we could see that they too have significant potential as plant crops for alternative livelihood.

With some crop options like Cissus sp. and Aspargus sp. we failed to get required growth in our experiment. So we could not conclude positively on few such species, which will need further investigation.

We then established a systematic approach in managing the alternative crops with the expertise provided by relevant experts in the medicinal plant field. The techniques of propagation, detailed cultivation methods, suggestions about raising of the planting stock, post planting treatments, manure/compost application, method of harvest, post-harvest management, and value addition techniques were developed as part of this phase. For the benefit of farmers, these were addressed in detail using the local language

Table 2 : Awareness and motivation workshops

Sr No.	Dates	Participants	Activities	Discussion/Outcome
1	May 2015	25	Common meeting for promotion of the concept	Farmers got to know for the first time about such crops which are in high trade (other than alternatives like Haldi which they have known)
2	10 July 2015	50	Meeting with local NGO and Biodiversity management committee representatives	Is the proposed model possible in Tadoba fringe and what will be the cost for such plantation
3	8 and 9th May 2016	150	A workshop with farmers having representation from all villages	Booklet with cultivation options was released, buyback guarantors for small crop yield visited this workshop

Table 3 : Experts who participated in the workshops

Name of expert	Institute/NGO/Other affiliation	Expertise
Dr. Rajendra Kale	Upvan	Buyback and cultivation of medicinal plants
Dr. Vrinda Kate	Shri Shail Medi farms	Cultivation and planting stalk
Poorva Joshi	Bio concepts	Medicinal plant trade and cultivation need
Ambarish Ghatate	Ayurvan foundation	Cultivation, buyback
Dr. Diwakar	State Horticultural and Medicinal Plant Board	Medicinal plants and role of government
IISER facilitators	National Medicinal Plant board	Grant options for individual farmers : Printed information on various grants
Vijay Dethe	Paryavaran mitra	Biodiversity Management Committee, People's Biodiversity Register, and community rights

Figure 2 : Marathi booklet and information sharing

Figure 3 : Workshop

Figure 4 : Training farmers

Figure 5 : Field training and technique standardization

(Marathi) in a booklet "Aushadhi vanaspatinche krushikaran : Ek garaj, Ek upay" (24).

Phase 4 : Awareness and motivation program

To disseminate the above information and to carry out meaningful interaction with locals we organized multiple workshops, facilitated by the research team. These workshops also helped us to validate and work through the suitability of the concept. The schedule, structure, and outcomes of these workshops are summarized in Table 2. The experts who participated in these workshops are listed in Table 3.

The booklet developed for these workshops will act as a tool that can be used to replicate this innovative and practical model for all forest fringes and creating best-practice guidelines. This booklet is developed with special focus on all local farmers as target audience. It gives all information related to cultivation methodology and buy back in the local language.

Figures 2-5 show a few glimpses of meaningful interactions during the workshops and fieldwork.

Discussion and recommendations

Owing to the vicinity of forests, buffer zones of Protected Areas have distinct advantages in agriculture such as good ground water levels and availability of green manure. The main problem of these areas is crop-raiding animals. The problem needs to be addressed at multiple levels including measures to reduce the damage, encouraging alternative crop species which are non-palatable to herbivores, along with alternative livelihood options (9). The innovative solution proposed here will help in supporting the current agriculture based livelihoods and also support conservation of wildlife by reducing human-wildlife conflicts. With simple value addition techniques, the

produce can be made available for small scale medicinal industry establishing new employment strategies for the youths in such affected regions. Farmers can scale up the production if they form their own cooperative society and adopt appropriate post-harvest technologies, value addition and QPM (Quality Planting Materials) management. It is also possible to have purchase tie-ups with the herbal medicine industry.

It is expected that the venture will be independently run by the community after a certain period of intervention and guidance from the research team, thus improving their standard of living.

One major advantage of the TATR forest is that being a tiger reserve, it attracts a large number of tourists. Subsequently, selling some value-added produce from these medicinal herbs to tourists can provide additional business to the locals. For example, herbal tea or dried medicinal produce in packets can be sold to tourists.

The core concern of the study was to offer a solution to reduce the crop raiding and subsequently to provide economic alternative to the farmers to fulfil their livelihood necessities. So we developed a workable model that involves local people towards wildlife conservation and will contribute towards mitigating man-wildlife conflict issues. Our study addresses biodiversity conservation, human-animal conflict, rural development, crop raiding, employment strategies, diversification, and behavioural development of the community over their territory.

In this study, we also analysed the value chain for medicinal plants produced by village-based marginal farmers and homestead growers. We established linkages with buyers and made the information available to farmers (24). The booklet produced in this study addresses the distribution channels, purchase locations for seeds and fertilizer, water supply for the plants, technology inputs, etc. We also suggest an improved value chain system through economic coordination that links production with the enhancement of the producers' livelihoods. Through the research, we could do a market survey for the produce. With two potential buyers interested, we took forward the concept in a meeting between farmers and buyers. Commitment of buying the produce was offered by buyers. During this meeting, to avoid middlemen, buyers even promised farmers to the pick-up of primary processed harvest. With this successful intervention, now we want to help further in strengthening such linkages for the benefit of farmers.

As a future prospect, the diversification of this project and commencement of further research and development pertaining to this project will be initiated to sustain the livelihood option in the form of medicinal plant cultivation. This innovative enterprise may contribute in formalizing the informal medicinal plant sector in several ways. Policy supporting the formalization of such businesses and subsidies (a few are already available through National Medicinal Plant Board, Delhi for clusters of farmers) for medicinal plant growers in wildlife conflict areas may contribute to the betterment of these communities.

Conclusion

The research suggests that the diversification of agriculture in man-wildlife conflict areas will be useful for livelihood enhancement. A closer linkage between the producers and processors of medicinal plants through direct farmer participation could result in a multitude of benefits to both, in terms of price, quality, lead time and overall improvement of the supply chain.

This work will create awareness regarding alternative livelihood options in the form of non-palatable medicinal plant cultivation, and in meeting the demand of raw materials required for herbal medicine industries. This pilot study has provided an important starting point for research, training, and knowledge sharing about cultivation and post-processing practices of medicinal plants. It is important to develop and adopt these plants as a crop species to create a successful model for alternative livelihoods.

References

Arnold, J.E.M. and Perez, M.R. (2001) Can non-timber forest products match tropical forest conservation and development objectives? Ecological Economics, 39, 437–447.

Bayani and Watve (2015) Crop depredation by wild herbivores at the western boundary of Tadoba-Andhari Tiger Reserve (TATR) Chandrapur, Maharashtra, India. A comprehensive report submitted to The Department of Forest, Maharashtra State.

Bawa, K.S. and Gadgil, M. (1997) Ecosystem services in subsistence economics and conservation of biodiversity. In Nature's Services: Societal Dependence on Natural Ecosystems (ed.G.C. Daily), pp. 295–310.

Bayani A, Tiwade D, Dongre A, Dongre AP, Phatak R, Watve M (2016) Assessment of Crop Damage by Protected Wild Mammalian Herbivores on the Western Boundary of Tadoba-Andhari Tiger Reserve (TATR), Central India. PLoS ONE 11(4):

e0153854. doi:10.1371/journal.pone.0153854
Caroline H., Medzhidov R. and Milner-Gulland E. J. (2011). Evaluating the relative effectiveness of alternative conservation interventions in influencing stated behavioural intentions: the saiga antelope in Kalmykia (Russia). Environmental Conservation 38 (1): 37–44.
Compendium of guidelines and circulars issued by Project Tiger directorate
Freya A. V. St John, Gareth Edwards-Jones A and Julia P. G. Jones (2010) Conservation and human behaviour: lessons from social psychology, Wildlife Research 37, 658-667
Fungo, B. A review of crop raiding around protected areas: Nature, control and research gaps. *Environmental Research Journal* 2011, 5(2):87-92.
Guerbois, C., Chapanda, E., and Frtiz, H., Combining multiscale socio-ecological approaches to understand the susceptibility of subsistence farmers to elephant crop raiding on the edge of protected areas. *J. of App. Ecol.* 2012, 49, 1149-1158.
Kala C.P., Farooquee, N.A. and Dhar, U. (2005) Traditional uses and conservation of timur (Zanthoxylum armatum) through social institutions in Uttaranchal Himalaya, India. Conservation and Society, 3, 224–230.
Karanth, K.K., Curran, L.M. and Reuning-Scherer, J.D. (2005) Village size and forest disturbance in Bhadra Wildlife Sanctuary, Western Ghats, India. Biological Conservation, 128, 147–157.
M. D. Madhusudan; (2003); Living Amidst Large Wildlife: Livestock and Crop Depredation by Large Mammals in the Interior Villages of Bhadra Tiger Reserve, South India; Environmental Management Vol. 31, No. 4, pg 466–475. 10. Lisa Naughton-Treves, Adrian Treves et al; (1998); Temporal patterns of crop raiding by Primates: linking food availability of crop lands and adjacent forest
Mahapatra, A.K., Albers, H.J. and Robinson, E.J.Z. (2005) The impact of NTFP sales on rural households' cash income in India's dry deciduous forest. Environmental Management, 35, 258–265.
Marshall, K. White, R., and Fischer, A., Conflicts between humans over wildlife management: on diversity of stakeholder attitudes and implications for conflict management. *Biodiversity Conservation* 2007, 16,3129-3146.
Michael J. M. and Dayer A. A. (2004). Concepts for Exploring the Social Aspects of Human–Wildlife Conflict in a Global Context. Human Dimensions of Wildlife, 9:317–328.
Milind Watve, Abhijeet Bayani, Samriddha Ghosh (2016) Crop damage by wild herbivores: Insights obtained from optimization models. Current Science, v. 111, pp. 861-867
Milind Watve, Kajal Patel, Abhijeet Bayani and Pramod Patil (2016) A theoretical model of community operated compensation scheme for crop damage by wild herbivores, Global Ecol Conserv 5, 58-70.
Nagothu Udaya Sekhar (1998); Crop and Livestock depredation caused by wild animals in protected areas: The case of Sariska Tiger Reserve, Rajasthan, India;
Published booklet – Aushdhi vanaspatinche krushikaran – ek garaj ek upay, 5 June 2016
Rai, N.D. and Uhl, C.F. (2004) Forest product use, conservation and livelihoods: the case of Uppage fruit harvest in the Western Ghats, India. Conservation and Society, 2, 289–313.
Report ISBN: 92-9225-296-8 Secretariat of the Convention on Biological Diversity
Saterson, K., Christensen, N., Jackson, R., Kramer, R., Pimm, S., Smith, M. and Wiener, J. (2004) Disconnects in evaluating the relative effectiveness of conservation strategies. Conservation Biology 18: 597–599.
Sinha, A. and Bawa, K.S. (2002) Harvesting techniques, hemi parasites and fruit production in two non-timber forest tree species in south India. Forest Ecology and Management, 168, 289–300.
Sukumar, R., Ecology of the Asian elephant in southern India. II. Feeding habits and crop raiding patterns. *J. of Trop. Ecol*., 1990, 6,33-53.
Sutherland, M., Pullin, A., Dolman, P. and Knight, T. (2004) The need for evidence-based conservation. Trends in Ecology and Evolution 19: 305–308.

Silent Conflicts – Human-wildlife interactions in urban spaces

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Abstract

This is a conceptual paper which analyses incidents of human-wildlife conflicts occurring in urban spaces. To assist in the choice of mitigation measures, the author proposes a categorization for the urban conflicts. The discussions and categorization are based on study of research papers, media reports, discussions with citizen and wildlife experts and the author's own observations during the last 20 years of living in Pune city.

The author proposes two categories of human-wildlife conflict. The first are 'violent conflicts' which are intended to prevent or remedy an animal intrusion. Such conflicts occur with animals such as leopards, snakes and monkeys which intrude into urban spaces. Violent conflicts are reported by media and studied by the research communities. The other category proposed is 'silent conflicts'. These are conflicts arising inadvertently out of human actions, and with no intention to harm animals. Such conflicts go unnoticed and often happen due to ignorance of the possible aftermath.

The author proposes different mitigation approaches to each of the categories, including the skills required in their implementation.

Keywords : *Sahyadri, Northern Western Ghats, Rocky plateaus, Windmills, Windfarm impacts, Area mapping, Ecological management plan*

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Introduction

In a tropical country like India, wildlife were the earliest inhabitants of areas, which are now our cities. However, a burgeoning human population and inevitable habitat modifications that followed, have displaced many of the original inhabitants. The few species that adapted to the human intrusion, continue to reside in urban parks, nooks and gardens, but the others have long moved away. Many of the original inhabitants are replaced by the common generalist species due to which the urban agglomerations have lost faunal uniqueness which still exists in some rural areas. India has 20 cities with over 2 million inhabitants. Over 31% Indians live in urban areas (Ministry of Home Affairs, 2011) and the growth continues. In the world, by 2025, about 136 new cities are expected to enter the top 600, all of them in the developing world (McKinsey, 2011). The urge to urbanize India has its roots in the Seventh five-year plan, which made a passing mention of the need for urban agglomeration. The Eleventh five-year plan considered urbanization as the '..locus and engine of economic growth' (Planning Commission, 2007) and made it a planning agenda. However, even before independence, rural population has been drawn to India's cities, because of the economic opportunities available. The level of urbanization in India increased from 17.6% in 1951 to 23.7% in 1981 and 27.8% in 2001 (Mohan and Dasgupta, 2004) and the expanse of Indian cities continues to grow. Urban sprawls have replaced mangroves (Valiela, Bowen, and York, 2001), pristine

forests (Seto, Güneralp, and Hutyra, 2012), flattened hills and diverted rivers (Grimm, et al., 2008). All over the world, urbanization has placed severe stress on the fauna (McKinney, 2008) and in many cases driven them out (Rudel, et al., 2005). If the world population follows the current trajectory, urban land cover is expected to increase by 1.2 million km 2030, which is nearly three times that of circa 2000 (Seto, Güneralp, and Hutyra, 2012). The growth of cities would intensify human-wildlife conflicts (human-wildlife conflict) resulting in extensive destruction of habitats and loss of biodiversity.

Even as the urban biodiversity diminishes, much of human-wildlife conflict studies focus on forest, rural and peri-urban areas, while conflicts in urban spaces are less studied. In India, leopard and monkey intrusions in cities are common incidences and a significant body of research is available on them. However, hardly any studies are available on many other species which are in human conflict in urban spaces. One interesting study on retreating wildlife in Pune enumerates the species distribution in the city and discusses the reasons of conflicts. The paper makes a comparison of Pune and Bangalore urban areas (Nalavde, 2006) and provided useful data for this article.

This article focusses on urban human-wildlife conflicts and proposes a classification of urban human-wildlife conflict into two distinct categories. These are discussed with specific cases of from Pune, Mumbai and Nagpur. Feral species are not covered and the more numerous conflicts on farmlands are not in scope of this article. The discussions which follow are based on the author's personal experiences, reviews of published and unpublished literature, news in various media and discussions with citizens.

Importance of urban biodiversity

Urban wildlife is a valuable resource. Increasingly, architects and landscape planners are putting efforts to conserve non-human life within urban spaces. The importance of urban biodiversity has been well discussed in literature. Urban biodiversity contributes to the enjoyment of nature (NWRC, 2010) and can be an indicator of ecosystem health (Saldiva and Bohm, 1998) (D.J. Rapport, 1998). It has recreational, aesthetic and spiritual values which are not easy to quantify but add to the uniqueness of the city (Grimm, et al., 2008). For example, the congregation of various water birds near the Bund Garden bridge in Pune city, was a unique feature. This area was identified by Prakash Gole to be protected and subsequently declared as the Mula-Mutha bird sanctuary, probably one of first such urban space for fauna (Brahme, 2002). The sanctuary was a unique feature of the city while offering recreational opportunities to its citizen. Similarly, the Sanjay Gandhi National Park at Borivali in Mumbai lends a uniqueness to the city.

Even as the benefits of a rich urban biodiversity are well known, of even greater importance is the 'intrinsic value' of wildlife (Boyle and Bishop, 1987), which is the inherent worth of wildlife as an end in itself (Callicott, 2003). In the process of development, this is often overlooked. Many cities were originally established in riparian areas, ecological transition zones, or on land reclaimed from mangrove forests (Kuhn, 2004) (Dearborn and Kark, 2009). These areas contributed to ecosystem services and provided habitat and food to non-human beings. The historical records of Mumbai show that in 1670 several islands were reclaimed by the British government by deforesting mangroves. The islands were joined into one continuous landmass (SPG Marine Ecology Centre, 2006). The mangrove destruction has resulted in a significant reduction in the photosynthetic capacity of the region and displaced many species which breed and live in mangrove swamps. The Indian Constitution acknowledges the intrinsic value of all forms of life. Article 48A of the Indian Constitution places responsibility on the state to "*…protect and improve the environment and safeguard forests and wildlife of the country*." 51A states "*…it shall be the duty of every citizen of India to protect and improve the natural environment …and to have compassion for living creatures*." This article was cited by the Supreme Court in the case of displacement of Gir lions, where the Court specifically mentioned that the "*…every species has the right to live…*" and that "*…our approach should be eco-centric and not anthropocentric…*" (Necessity of a second home for the Asiatic Lion, 1995). The Court goes on to define the terms eco-centric and anthropocentric and further clarifies all doubts with the statement "*…in other words, human interest does not take automatic precedence and humans have obligations to non-human beings independently of human interest*." A similar ruling was passed later in 2005 in the case of the Asiatic wild buffalo.

The dazzle of urbanization and the pursuit of anthropogenic activities seems to have made mankind less sensitive to non-human beings, the original inhabitants of cities. While there are very few studies on the magnitude of urban human-wildlife conflicts, as the population and man-made infrastructure increases, so does the conflict. Not all are reported by the media, only the ones which are potentially detrimental to

humans make it to press. The ones which go unnoticed may probably be do more harm to the environment and to the sustainability of future generations of mankind.

Two types of human-wildlife conflict

The World Wide Fund for Nature (WWF) defines human-wildlife conflict as "any interaction between humans and wildlife that results in negative impacts on human social, economic or cultural life, on the conservation of wildlife populations, or on the environment" (WWF, 2005). Farmers are perhaps the heaviest sufferers from wildlife damage to crops and have been in conflict with them probably since the arrival of agriculture. But, other than these intrusions, rural residents are generally more tolerant to wild animals (Messmer, 2009) than city dwellers, who often overlook their existence (Lowry, Lill, and Wong, 2012). Considered as the economic engines of a nation's GDP, cities draw huge investments in infrastructure, which are intended to support this role. Cities have altered natural ecosystems to achieve specific economic ends. Something which obstructs this activity, is not welcome as is apparent in the human-wildlife conflicts which take place in urban spaces. In India, the development of urban infrastructure, did not set a clear prioritization for the conservation of species in their habitats. This has resulted in human-wildlife conflicts, some of which go unnoticed. The onslaught of economic growth has resulted in increased conflicts, and as they continue to rise, its effects on ecosystems services and food chains will soon show up. It is then imperative that there are mitigation measures in place to improve the situation. However, the variety of urban conflicts being encountered may require different approaches to alleviate the harm to animals. Towards this end, the author proposes a categorization of urban human-wildlife conflicts, which would need separate approaches to mitigation. The first category is termed as **'silent conflicts'**. These conflicts arise from the usual economic activities of man and are characterized by two factors :

i. Inadvertent harm to animals : Human actions are done in their own interest, and there is no intention to harm any species.
ii. Unnoticed result of human actions : The result of these actions, on the animals, is not noticed by the proponent.

The second category are the **'violent conflicts'**. In this type of conflict, there is :

i. Intended harm : Human actions are directed towards an animal, to reduce a risk or threat posed by them.
ii. Desired outcome : The outcome of these actions on the animal are intended and noticeable.

Here, human actions are directed towards removal, reduction or killing the animals. Incidences of leopard and monkey intrusions are 'violent' conflicts.

The article discusses both the types of conflicts with examples. A representative list of these conflicts is shown in Table 1.

Silent conflicts in urban areas

The diminishing population of honey bees in Indian cities is a striking example of a silent human-wildlife conflict. About twenty years ago, an old growth tree in the botanical garden of Fergusson

Table 1 : Categorization of Urban Conflicts

	Human actions leading to conflicts	**Representative list of affected species**
Silent conflicts	Covering soil with tar/cement, building walls to water bodies, removal of old unused buildings, increase in vehicular traffic, mobile phone towers, electric cables, plantations of exotic trees, air and water pollution, deformation of hills, firecrackers, festival and victory celebrations	Honey bees, bats, mongoose, black naped hare, house sparrows, larks, pipits, chats, swifts, harriers, baya weavers, barn owls, spotted owlets, falcons, quails, francolins, Indian eagle owl, bar headed geese and other migratory birds, variety of fishes, amphibians and insects.
Violent conflicts	Fencing, killing, driving away, poaching, use of pesticides, traps and baits, scaring	Leopards, snakes, monkeys, civets, honey bees, bats, pigs, porcupine. Besides several house and garden pests.

College, Pune, used to host over 25 bee hives. Not a single hive is recorded on this tree in the last few years. There are several other instances of such acts of disappearance in Mumbai and Pune[1]. While there are several reasons for this, scientists believe one of the main contributor is the electromagnetic radiation from mobile phone towers[2]. The World Health Organization (WHO) has acknowledged a short-term effect of this radiation on humans and is researching the long-term effects[3]. It is thus not injudicious to assume that the radiation would pose a risk to bees and other fauna. Considering the growth of mobile phone business in India, this risk is expected to increase over the years. By March 2013, India had an estimated 868 million mobile phone users which are operational through a network of over 500,000 telecom towers (CPCB, 2014). The densely populated Indian cities are riddled with cellular network towers which operate continuously. A recent news report mentioned that 108 mobile phone towers in India exceeded the standard radiation limits[4]. Another threat to the bees is from the extensive use of pesticides in urban parks and gardens. These toxins reach bee larvae through the pollen collection and can kill them (Gutenberg, 2016). One particularly damaging pesticide is neonicotinoid which has sub-lethal effects in bees and a strong evidence linking their use to losses in the bee population (Woodcock, et al., 2016). Other conflicts arise because of exotic tree plantations in parks and on avenues, cutting down of old-growth trees and air and water pollution in the cities. Newly developed suburban areas of Pune like Baner, Pashan and Bawdhan had several bee colonies before the construction frenzy took place. These conflicts are not visible to urban dwellers and until recently, the vanishing urban bee population did not catch media attention. But there has been substantial research and media awareness in the western world, which is evident from United Nations and international magazines carrying the reports.[5]

Another example of a silent human-wildlife conflict is the expulsion of bat colonies from cities. There have been increasing instances of disappearance of bat roosts from Pune and Mumbai[6]. Studies have recorded bat roosting sites in Indian cities. The Indian short-nosed fruit bat Cynopterus sphinx, the Indian flying fox (*Pteropus giganteus*), the cave dwellers (*Hipposideros speoris*) and the wrinkle lipped bats (*Tadarida plicata*), among others, have been noted in Pune city. Over the years, their roosting sites have reduced and their numbers diminished because of several reasons. A major silent conflict which confronts the fruit bat population is the changing flora of the city. Plantations are done based on economic and aesthetic considerations and this changes the food availability for bats. An increase in the number of flying foxes is noted in Pune. One reason for this could be the popularity of fruit tree plantations in urban gardens. However, the short-nosed fruit bat population in Pune has reduced because of the silent conflict happening with its habitat. These bats prefer dark and humid ceilings of stone buildings and trees like the Ashoka (*Polyalthia longifolia*) and Fish-tail palm (*Caryota urens*). Old Wadas and temples within the old part of Pune city provided such a habitat. They are being replaced by cement buildings and the old growth Ashoka trees are cut down. Old-growth native trees give way to exotic garden varieties. Decorative palms are planted in public gardens, Rain trees (*Albizia saman*) are popular avenue trees and Glyricidia (*Gliricidia sepium*) and Eucalyptus (*Eucalyptus globulus*) (Yardi and Korad, 2001) are planted on hills. These trees are not preferred for roosting by the bats and are therefore equivalent to a habitat loss for them. Large scale habitat loss has had an adverse effect on bat populations. Similar case has been noted in the wrinkle-lipped bats. Their colonies in Nana Wada, an old stone construction public building in Pune, have disappeared because their shelter was removed. The third silent conflict arises from increased vehicular traffic and noise. There were records of bat colonies roosting under bridge arches in Pune, but are no longer there. The heavy traffic and the subsequent increase in oscillations of the bridge may have disturbed them. City noise takes its toll on bird mate finding too. There are cases where bird mating calls are drowned by vehicular noise which hampers breeding. The growing expanse of city areas necessitates electric wires to be laid over long distances. These pose a lethal hazard to large bats, who are often seen electrocuted. All these factors have been detrimental to the bat population in cities.

Mongoose (*Herpestes edwardsii*) have long been residents of Indian cities and are often seen in residential societies. They have lived in harmony with human beings in cities. In Pune, mongoose were extensively present in the old city areas. The 'wadas' or the old houses and temples had ample space surrounding them, large trees and abundant undergrowth. The mongoose had safe hiding places and a supply of food in the rats that thrived here. They could move safely from one location to another through the small canals and waterways within the city. A pair of mongoose is often sighted in the Mutha river bank near opposite

Omkareshwar temple in Pune, which is probably one of the last few areas in the city where human interference is minimum. The pair can safely move along the bank in search of food. However, such places are shrinking and in recent years, the mongoose population within the old city has reduced drastically because of large residential structures coming up in place of the wadas. The construction activity of buildings, lasting over a year is highly intrusive for these animals. The completed structures hardly leave any hides and the boundary walls obstruct their passages. The Ambil Odha (canal) which passes through Padmavti has dense thickets along its sides. Mongoose have been using this for movement in search of food. A wall is in the process of being built along the canal, which will cut off the passage movement for the mongoose and other wingless creatures (see picture 1). The growing nuisance of stray dogs has affected mongoose too, who are chased by them. On the other hand, there are reports of mongoose population in suburbs like Aundh, Baner and Bawdhan going up. Garbage stacks in open spaces attract hordes of rats. The abundant rat population can support the mongoose, who are seen congregating around the garbage stacks. One large garbage stack in Aundh is reported to have at least four mongooses. The mongoose are harmless to humans and live in harmony, and keep a check on rat populations. But their existence is not even considered when undertaking public works modifications in cities which can potentially interfere with their lives. Urban planners are 'blind' to this conflict as it does not affect humans.

Some of the avian species significantly affected by habitat modification are Barn Owls (*Tyto alba*) smaller raptors like Shikras (*Accipiter badius*) and Kestrels (*Falco tinnunculus*). Barn owls were usually sighted at dusk in the old peth areas of Pune city. As the dense foliage trees reduced in numbers, they have adapted to living on buildings and man-made structures where they are exposed to human contact. Spotted owlets (*Athene brama*) live in trees and cannot adapt to man-made structures like the barn owls. Their population remains in a few areas in Pune like the Pune university and various college campus, cemeteries, hills and wooded localities like Nav Sahyadri society, Padmavati and the Mula-Mutha sanctuary. Recently three large Gulmohur (*Delonix regia*) trees were pulled down in S. P. College, in the old city area. These trees were a favorite roost for a pair of spotted owlets. The pair has not been seen since the trees were cut down. Another threat to these raptors is the bright city lights and signage at nights. Such is the brightness that house sparrows have been spotted feeding on a street in Aundh at 2:30 am. This is a significant change in avian behavior. Some years back, the sagacious Indian eagle owl (*Bubo bengalensis*) was frequently sighted on the Vetal hill, where it had a relatively quiet habitat and ample food. However, the Vetal hill has grown to be one of the most preferred exercise spots in the city. The reticent owl is no longer seen here now. The number of Shikras has diminished in downtown Pune. Here they face hostility from the growing crow population which thrives around human settlements. Crows often mob the raptors and with intimidating behavior. This is a nuisance especially to the barn owls. The reduction in barn owls and shikras shows up in the rising population of three-striped palm squirrel (*Funambulus palmarum*).

Another case of a silent conflict takes place when open ground in cities is covered with tar, cement or paver blocks. This effectively shuts off the access to soil for various insects like bugs, beetles and ants. Moreover, the impermeable ground cover prevents water puddles from forming and dragonflies and damselflies are deprived of their habitats. Frogs, which were once common in the city, have lost their habitats due to the land covers. Lawns are sprayed with insecticide, which has detrimental effect on insects. The loss of insect diversity, in turn affects the food availability for the insect eating birds and their populations have dwindled. In such urban settings, the avian diversity is being replaced by red whiskered bulbuls (*Pycnonotusjocosus*), red vented bulbuls (*Pycnonotuscafer*) and common myna (*Acridotheres tristis*).

Such silent conflicts occur with many other species,

Wall being constructed along Ambil odha

and are hardly realized. One incident reported from Ambazari lake, Nagpur is about a colony of hundreds of Swifts (species unconfirmed) who resided in a groove between a sloping roof and wall. The old house was pulled down this year and the Swifts are no longer seen here. They are not gregarious birds and in all likelihood, might not have found another suitable nesting site in the neighborhood. Similarly, the increased pollution in Ambazari lake, in the heart of Nagpur, has been a deterrent for the Red crested pochards (*Netta rufina*) used to come here. The urban predilection for aesthetic trees has killed many a thorny tree like the Babhul (*Acacia nilotica*). This destroys nesting sites of charismatic nest weaving birds like the Baya. Plantations on grassland habitats, like the Gliricidia (*Gliricidia sepium*) plantation on Vetal tekdi, has driven away the black naped hares (*Lepus nigricollis*) which were once seen here. Sewage dumped in the Mutha river has polluted the water to a dark grey colour. Pied kingfishers (*Ceryle rudis*) which were once recorded here, are unable to fish in this water. Another large scale silent conflict happens when cities spread to adjoining open lands spaces and fill them up with buildings. 'Wastelands' are foraging grounds for several larks, pipits, chats and harriers. They are displaced when open spaces are replaced by buildings. This is evident in the Hinjewadi suburb of Pune, where a large information technology park came up on a wasteland in 1995. Over the last 20 years, the park has extended into three phases covering 680 hectares and another 460 hectares are to be added soon. This is a total loss of habitat for the open-land birds[7] .

Another growing menace to urban wildlife is from the nature of urban celebrations. Festivals, weddings, sports victories, political wins and many other occasions are being celebrated with firecrackers, excessively loud music and bright lights. These are frightening for the animals. This author kept a honey bee (*Apis cerena indica*) colony at home in Pune. On the Laxmi Pujan day of Diwali, the shopkeepers blast firecrackers on the 'muhurat' or auspicious time. The sound and smoke scared off the colony and they swarmed to a safer place.

Violent animal conflicts in urban spaces

Several fauna pose some form of hazard to humans and this is the source of violent conflict between these species and humans. By far the most discussed cases of violent urban human-wildlife conflicts, in India, involve leopards. The growing leopard population and their dwindling wild food supply pushes them to urban area fringes, which were once their territories. They prowl into residential areas at night and pose a serious threat to humans and domesticated animals. Such cases are encountered in Mumbai suburbs of Borivali where leopards stray away from the Sanjay Gandhi National Park and enter residential complexes. In many cases leopards are beaten to death or are trapped and killed (Figure 2). In 1986 there was a case of a leopard walking into a large industrial premise in Pune. The leopard stayed back in the premises for two days and the factory was shut down and production was lost. Leopard and snake conflicts are some of the most visible forms of urban human-wildlife conflict. As they threaten human life they are extensively covered by media.

The other notable species with whom humans violently engage in conflicts are small Indian civets (*Vivvericulaindica*), common palm civets (*Paradoxurushemaphroditus*), langurs (*Semnopithecus entellus*), macaques (*Macaca radiata*) and snakes. These animals are purposefully driven away or killed by urban inhabitants. There is a growing nuisance from civets, in the new suburbs of Pune city. Civets have adapted to living around human dwellings and occasionally enter houses in search of easy food. They are known to boldly raid kitchens to eat fruits, leftovers and scraps. Civets are a nuisance in some of the newer residential areas of Bawdhan, Sus and Pashan, where their numbers have increased. In one large residential complex in Bawdhan, the palm civets climb up drainage pipes and raid apartments on the fifth floor. The residents have modified their windows and drain pipes to stop them from entering. Due to their fierce looks and foraging behavior, there have been incidences of civets being stoned or beaten to death. There are incidences of civets running away from human

Leopard beaten to death

wrath have been killed on roads (Figure 3). A similar treatment is meted out to any snake found near human dwellings. In one incident, a snake was caught on a fifth-floor apartment. The society promptly chopped down an old growth Umbar (*Ficus racemosa*) which was suspected to offer the climbing support to the snake. The tree and the snake were eliminated in the process. In the old parts of Pune city, cobras (*Naja naja*) have been recorded about 20 years ago. Today, the localities like Nav Sahyadri society, Patil estate, Padmavati, hills and areas near the river banks, have a population of checkered keelbacks (*piscator*), rat snakes (*Ptyas mucosa*) and green keelbacks (*Macropisthodon plumbicolor*). Due to loss of habitat, the snakes enter residential areas and backyards where they are spotted and killed. In many cities, NGOs and individuals are now offering snake rescue services. While there is no documented study, such services can potentially reduce the snake deaths in India. The rescued snakes are either relocated to neighboring woodlands or kept in snake parks. Scientists have expressed concern about the survival rate of the relocated snakes and one study shows deleterious effects on relocated King cobra (Barve, et al., 2013). In the Konkan region of Maharashtra, the red sand boa (*Eryx johnii*), locally called the 'dutondya' is extensively hunted for its alleged magical powers. This has reduced their population in Konkan. In India, myths and perceptions exist about snakes, which too, is detrimental to their survival. While many organizations are spreading awareness on their conservation, most urban snakes end up facing a gruesome death.

In addition to the silent conflicts discussed earlier bees and bats fall prey to violent conflicts too, a

Indian Palm Civet killed on road after being chased away

residential colony which has a bee hive, would request its removal by the local administration. The usually docile bees are feared for their stinging bite. In Pune, teams of migrant Adivasis wander the streets in search of bee hives. They climb the trees, drive away the bees and sell off the honey and wax. The author spoke to one team and they boasted of having removed over ten hives in the month. There are instances when residential societies with honey bee colonies have called pest control services for their removal. They spray toxins which kill most of the bees. Such acts will hasten the decline of bees from urban spaces and must be stopped. A similar predicament faces bat colonies. Bats are looked upon as dark and ferocious creatures and considered a nuisance by urban dwellers. They gorge fruits in huge flocks, make an unpleasant noise and spoil the area with their droppings. These perceptions have led them to being driven out. A recent case at the Kalaghoda Museum premises in Colaba, Mumbai, had the staff injecting chemicals in trees to stop their roosting[8]. Like the bees, removal of bat colonies too, is considered to be in human interests.

Monkeys are a menace in urban spaces. As they roam fearlessly in gangs and feed in urban gardens, they are in continuous conflict with humans. Their ability to adapt to new habitats has helped them thrive in dense human settlements. They have learnt to intimidate humans with their fearsome teeth and have turned into pests. In a major incident in 1998, several people were injured as a horde of monkeys stormed into Srinagar and attacked anyone who tried to cross their path. They were driven by hunger and freezing temperatures and raided restaurants, hotels, fruit and tea shops, houses and government offices in search of food. Shrieking menacingly, they barged into an old royal palace and ransacked it and the adjoining state government offices (Sathu, 2017). rural India, some farmers are issued gun licenses and would routinely shoot the gangs; but there is hardly any way of controlling them in cities. In 2007 the wildlife department in Delhi captured over 19000 monkeys and relocated them to Asola Bhatti mines outside Delhi. But the monkeys entered the nearby Sanjay Colony and troubled the residents there. Culling and sterilization are expensive and not easy to implement. As their populations grow, so does the conflict.

The urban airports are another source of violent conflicts in cities. Bird activity is not welcome in this area, lest it interfere with aircraft engines. There are no trees and the grasses are routinely sprayed with

pesticide to kill insects. Mongoose and civets climb over the wall and intrude are often killed.

Conflict mitigation strategies

Often, decisions involving wildlife issues in India have been controversial in India. This is mainly due to the differing objectives and values which every stakeholder has. Business communities prioritize economic growth, administration holds social interests important, NGOs fight for animal rights and citizen are unaware or unconcerned. Thus, the success of the conflict mitigation program depends largely on the ability of the decision makers to identify stakeholders and incorporate their values and objectives in the policy making process (Messmer, 2009). Guynn (1997) makes a list of elements of a successful conflict management process. These are (1) clearly defined objectives (2) clearly defined authority levels (3) participant agreement (4) inclusion of team building exercise (5) maintenance of continuity by not allowing substitutes (6) implementation of guidelines and activities that promote violent listening (7) achievement of success with smaller issues before addressing larger concerns. The author suggests adding one more point to this list – making stakeholders aware of each other's problems and objectives. This is important for a country like India, where an estimated 74% population[9] is illiterate and perhaps unaware of the multiple problems arising from human-wildlife conflicts.

Clearly, the resolution of both types of conflicts discussed here require separate approaches towards mitigation. In silent conflicts, the bottom line is the non-awareness of the problem in the perpetrators. Moreover, many of these conflicts are not easily observed and hence go unreported in media. Thus, even well-intentioned individuals or organizations may not get a chance to avoid their actions. The first step suggested towards reducing silent conflicts is increasing social awareness. While NGOs and other organizations have successfully created awareness campaigns in India, this can be driven by local and state governments as a means of preserving the local faunal peculiarities of the city. One such campaign is recently launched by the government of Nagaland[10]. The locals have lived off hunting but the alarming decrease in species diversity and reduction in populations of some keystone species has prompted the government to take up the awareness campaign. The government of Maharashtra has an ongoing awareness program on the leopard-human conflict[11], but that is a visible conflict. There is no similar example yet on the silent ones. The Royal Society for Protection of Birds (RSPB) has undertaken successful awareness campaigns in the past while in India the BNHS has been working on an Urban Biodiversity and Eco-restoration program in Mumbai. Increasing social awareness is challenging, but not impossible. Analytical and communication skills are essential in the mitigation of such conflicts. Use of social networking, digital media and innovatively conveying the message are important elements for its success. The next step is identifying key target groups which are involved in these conflicts and spreading awareness among them. Architects, builders, local government departments and corporate houses are some of the groups.

On the other hand, the 'violent conflicts' need a stakeholder approach. The diversity in stakeholders can complicate the situation. For example, in handling incidences of leopard intrusion, citizen, local government, wildlife department and NGOs working in nature protection could be the potential stakeholders. Each one could have a differing perception of the intruder and hence differing views on how to handle the situation. Handling violent conflicts is thus dependent on managing stakeholder differences, prioritizing the issues and negotiating the solution. The skills required here are different from the ones needed for silent conflict management. Moreover, there are tried and tested ways to overcome these conflicts. Some are successful while others delay the impact of the problem. Some of the popular one are – relocation (snakes, leopards, bees), protection in enclosures within the city (leopards), sterilization to reduce populations (monkeys, dogs), offering compensation to move out (usually used in threatened fauna habitats), killing (dogs, pigs, bats) and use of noise deterrents (monkeys). It is evident that some measures are anthropocentric, but humans have created conditions suitable for their growth and a control on their populations is imperative in many cases. Economic, social and personal benefits must be considered in mitigation of violent conflicts.

Conclusions

Urban wildlife in India is under severe pressure from the proliferation of human activities. Even though some species are a threat to life or human activities, many others die or move out unnoticed. If the biodiversity of the cities needs to be conserved and improved, it is crucial to increase the social awareness and take hard steps to mitigate the situation. The Indian Constitution and the government's commitment to the Sustainable Development Goals

makes it mandatory to preserve and protect all forms of life in the country. Indians have largely lived in a harmonious relationship with nature. It is of critical importance that we reconsider our priorities and bestow the same importance to nature as our forefathers once did.

References

Barve, S., Bhaisare, D., Giri, A., Shankar, P., Whittaker, R., and Goode, M. (2013). A preliminary study on translocation of "rescued" King Cobras (*Ophiophagus hannah*). Hamadryad, 36(2), 80-86.

Boyle, K. J., and Bishop, R. C. (1987). Valuing wildlife in benefit-cost analyses: A case study involving endangered species. Water Resources Research, 23(5), 943–950.

Brahme, N. (2002). Times of India. Retrieved from Conservation experts bat for bird, flora database of Mula and Mutha: http://epaper.timesofindia.com/Default/Layout/Includes/MIRRORNEW/ArtWin.asp?From=Archive&Source=Page&Skin=MIRRORNEW&BaseHref=PMIR%2F2010%2F09%2F20&GZ=T&ViewMode=HTML&EntityId=Ar00100&AppName=1

Callicott, J. (2003). The philosophical value of wildliife. In S. Armstrong, and R. Botzler, The Animal Ethics Reader (pp. 383-386). New York: Routledge.

CPCB. (2014). Awareness note on mobile tower radiation and its impact on environment. Central Pollution Control Board of India. New Delhi: CPCB. Retrieved from http://cpcb.nic.in/Note_Mobile_Tower_Radiation_UPCD_Div.pdf

D.J. Rapport, R. C. (1998). Assessing ecosystem health. Tree, 13(10), 397-402.

Dearborn, D. C., and Kark, S. (2009). Motivations for Conserving Urban Biodiversity. Conservation Biology, 1-9. doi:10.1111/j.1523-1739.2009.01328.x

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., and Briggs, J. M. (2008). Global Change and the Ecology of Cities. Science, 319(5864), 756-760.

Gutenberg, J. (2016, June 24). Neonicotinoid pesticides cause harm to honeybees. Retrieved from Science Daily : https://www.sciencedaily.com/releases/2016/06/160624135849.htm

Guynn, D. (1997). Miracle in Montana: managing conflicts over private lands and public wildlife issues. Transactions of the North American Wildlife and Natural Resource Conference, 62, pp. 146-154.

Kuhn, I. R. (2004). The flora of German cities is naturally species rich. Evolutionary Ecology Research, 6, 749-764.

Lowry, H., Lill, A., and Wong, B. B. (2012). Behavioural responses of wildlife to urban environments. Biological Reviews, 000-000. doi:10.1111/brv.12012

McKinney, M. L. (2008). Effects of urbanization on species richness: A review of plants and animals. Urban Ecosystems, 11(2), 161-176. doi:10.1007/s11252-007-0045-4

McKinsey. (2011). Urban world: Mapping the econmic power of cities. McKinsey.

Messmer, T. A. (2009). Human–wildlife confl icts: emerging challenges and opportunities. Human–Wildlife Conflicts, 3(1), 10-17.

Ministry of Home Affairs. (2011, January 2). Provisional Population Totals. Retrieved from Census India : http://censusindia.gov.in/2011-prov-results/paper2/data_files/India2/1.%20Data%20Highlight.pdf

Mohan, R., and Dasgupta, S. (2004). Urban Development in India in the 21st Century: Policies for Accelerating Urban Growth. Fifth Annual Conference on Indian Economic Policy Reform at. Stanford: Stanford Centre for International Development.

Nalavde, S. B. (2006). Retreating wild mammals of Pune Urban Area. Retrieved from Ranwa: http://www.ranwa.org/punealive/pamam.htm

Necessity of a second home for the Asiatic Lion, 337 OF 1995 (Supreme Court of india 1995).

NWRC. (2010). Reducing Urban Wildlife conflicts. Retrieved from US Department of Agriculture: https://www.aphis.usda.gov/wildlife_damage/nwrc/publications/factsheets/FS_urban_wildlife_conflicts.pdf

Planning Commission. (2007). Eleventh Five-year Plan. Retrieved from Planning Commission: http://www.planningcommission.nic.in/plans/planrel/fiveyr/11th/11_v1/11th_vol1.pdf

Rudel, T. K., Coomes, O. T., Moran, E., Achard, F., Angelsen, A., Xu, J., and Lambin, E. (2005). Forest transitions: towards a global understanding of land use change. Global Environmental Change, 15, 23-31.

Saldiva, P., and Bohm, G. (1998). Animal Indicators of Adverse Effects Associated with Air Pollution. Ecosystem Health, 4(4), 230-235.

Sathu, J. (2017, January 3). Electronic Telegraph Report. Retrieved from Facts and details: http://factsanddetails.com/asian/cat68/sub430/item2484.html

Seto, K. C., Güneralp, B., and Hutyra, L. R. (2012).

Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. In B. L. Turner (Ed.), Proceedings of the National Academy of Sciences of the United States of America, 109, pp. 16083–16088. Retrieved January 12, 2017, from http://www.pnas.org/content/109/40/16083.long

SPG Marine Ecology Centre. (2006). Godrej. Retrieved from Mangroves in Mumbai: http://www.mangroves.godrej.com/MangrovesinMumbai.htm

Valiela, I., Bowen, J. L., and York, J. K. (2001). Mangrove Forests : One of the World's Threatened Major Tropical Environments. BioScience, 51(10). doi: https://doi.org/10.1641/0006-3568(2001)051[0807:MFOOTW]2.0.CO;2

Woodcock, B. A., Isaac, N. J., Bullock, J. M., Roy, D. B., Garthwaite, D. G., Crowe, A., and Pywell, R. F. (2016). Impacts of neonicotinoid use on long-term population changes in wild bees in England. Nature. doi:10.1038/ncomms12459

WWF. (2005, January 3). Human Wildlife conflict manual: Wildlife Management Series. Retrieved from Panda.org: http://wwf.panda.org/index.cfm?uNewsID=88920

Yardi, K., and Korad, V. (2001). Bat Fauna of Pune city. Journal of Ecological Society, 13/14(1), 71-73.

Endnotes

1. http://timesofindia.indiatimes.com/india/Honey-where-are-the-bees/articleshow/51564223.cms http://punemirror.indiatimes.com/pune/others/Honeybees-dying-due-to-pesticides/amp_articleshow/44126329.cms http://mumbaimirror.indiatimes.com/mumbai/other/City-losing-its-buzz/amp_articleshow/16023124.cms
2. http://www.telegraph.co.uk/news/earth/wildlife/7778401/Mobile-phones-responsible-for-disappearance-of-honey-bee.html
3. http://www.who.int/mediacentre/factsheets/fs193/en/
4. http://www.huffingtonpost.in/2016/08/10/mobile-phone-towers-radiation/
5. http://www.newsweek.com/bee-populations-vanish-usda-tries-keep-them-fed-230271 http://www.un.org/apps/news/story.asp?NewsID=37731#.WHMmwn39Vw9
6. http://timesofindia.indiatimes.com/city/pune/Drop-in-Western-Ghats-bat-species-Study/articleshow/34987512.cms http://www.dnaindia.com/india/report-mumbai-bat-lovers-join-forces-to-save-their-leathery-little-friends-2013336
7. http://www.thehindubusinessline.com/todays-paper/tp-info-tech/hinjewadi-phase-iii-set-to-get-sez-status/article2196581.ece
8. http://www.dnaindia.com/india/report-mumbai-bat-lovers-join-forces-to-save-their-leathery-little-friends-2013336
9. http://timesofindia.indiatimes.com/india/Literacy-rate-up-but-so-is-illiteracy/articleshow/50749744.cms
10. https://ipr.nagaland.gov.in/NagaNews?ID=HUMAN%20ANIMAL%20CONFLICT%20MITIGATION%20AWARENESS%20CAMPAIGN%20ON%204th%20NOVEMBER
11. http://www.mumbaikarsforsgnp.com/docs/leopard_awareness_camp_report_SGNP.pdf

Vegetation character and species diversity of Panshet catchment

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Abstract

The present note elaborates the vegetation character and plant diversity in the Panshet Dam Catchment, studied during six months of field survey in 2014 (July-December) as part of a project undertaken by Ecological Society and supported by Global Forest Watch.

As floral species are directly related to climatic type, especially rainfall, therefore the Panshet catchment was divided into high, medium and low rainfall zones. The floral species survey was conducted in relation with these zones.

The focus of present study was to relate species composition with physical factors like altitude and climate. To study the vegetation character of the catchment, species level surveys of various vegetation categories like tall canopy forests, devrais, shrubbery and others, were undertaken and the species composition of each vegetation category was recorded. Moreover, species occurrence over rainfall zones was recorded. Identification of rare, endemic and specialist species was equally important to gauge the vegetation character and ecological value. Other observations included dominant species and invasive species.

Study Area : Panshet Dam Catchment

The Panshet dam is located near Panshet village at a distance of 45 km West of Pune city, Maharashtra, India. This dam impounds the water of river Ambi which originates in Western Ghats near a village Dapsar (Lat. N 18° 21" Long. E 73° 25") at an altitude of about 1200 MSL (Gole P., Tetali P., 1985).

The catchment area of 120.30 Sq. Km. encompasses a variety of land uses including village settlements, Devrais (Sacred Groves), shifting cultivation patches, dense shrubbery, scrubland, tall canopy, open grassland areas, exposed rock surfaces, riparian areas, monoculture stands, farm house schemes for urbanites, proposed townships, roads, agro industry and small industrial workshops (Ghate K., 2014). About 25 villages are scattered along both the sides of reservoir.

Within the Panshet catchment there are three rainfall zones - low, medium and high with average annual rainfall of 2000 to 3000 mm, 3000 to 6000 mm and 6000 to 9000 mm respectively (Ghate K., 2014). The rainfall drastically increases towards West of the dam as one travels towards the Western Ghats crestline.

These three rainfall zones provide different climatic conditions and create microclimates supporting specific vegetation type from moist deciduous to tropical semi-evergreen forest.

The Panshet Catchment area was studied by Ecological Society in 1985 for its status of animal and plant life with a focus on designing conservation plan

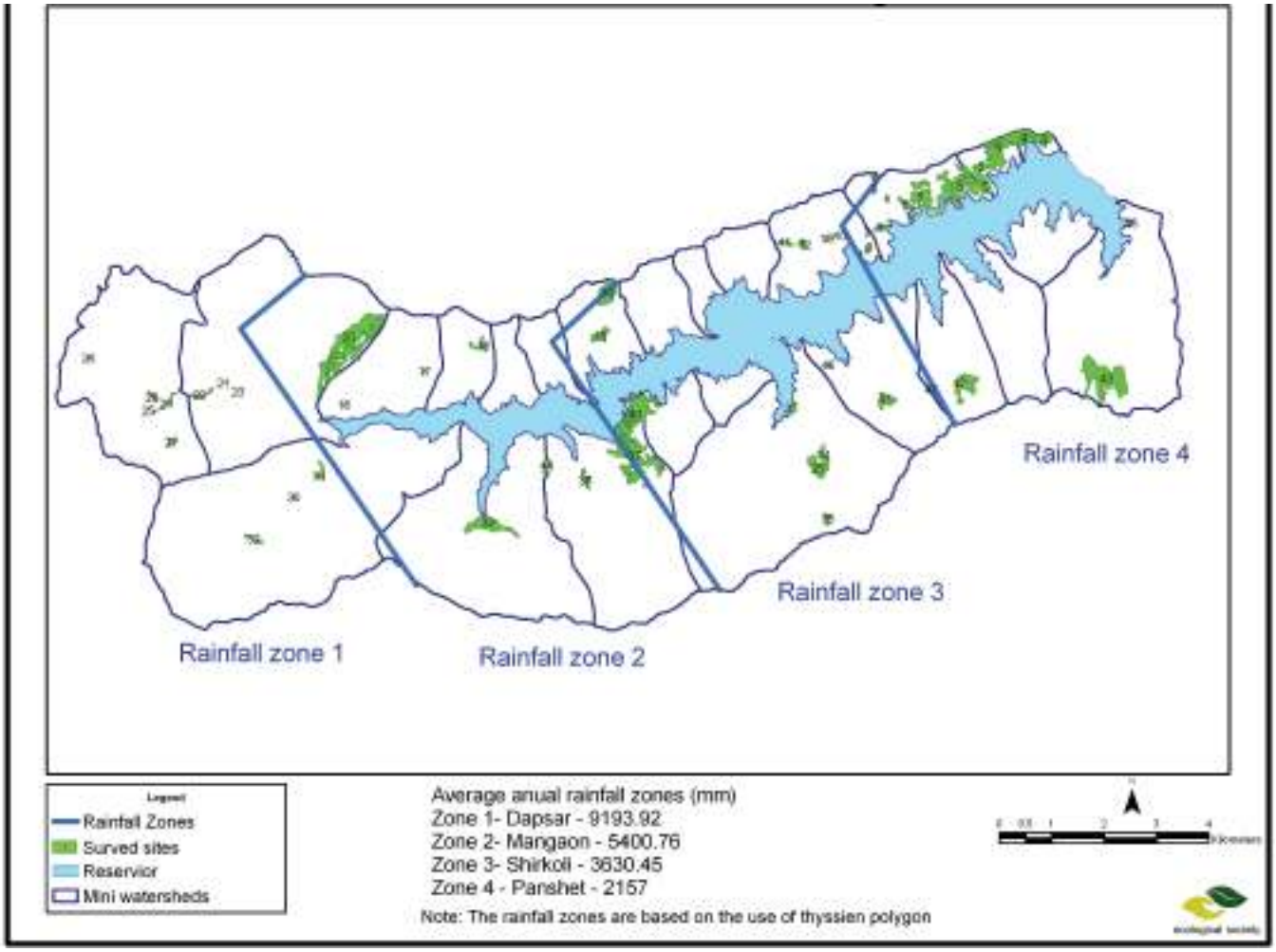

Diagram showing indicative rainfall zones in Panshet Catchment

(Ecological Society, 1985). The findings from this report about vegetation pattern and floral composition provided a baseline for the current survey.

Methodology used to document floral character and species diversity

A reconnaissance survey of the Panshet catchment was done and then sample sites were selected with the help of Google Earth images. A stratified random sampling approach was followed and 47 vegetation patches distributed across the three rainfall zones were identified for the survey (Karandikar M., Dumale V., Deshpande S., 2015). Among the 47 areas surveyed, 19 were in low rainfall zone, 15 in medium rainfall zone and 13 in high rainfall zone.

To study the flora of Panshet catchment, our team collected data about vegetation cover, species composition, occurrence, regeneration etc by Line Transect method. Observation of the landscape features was the base of the documentation. For this purpose, we recorded physical factors influencing vegetation like climate, altitude, slope, substratum (soil type and depth) and habitats.

The plant species were identified using Flora of Maharashtra, Botanical Survey of India (3 volumes) and The Flora of the presidency of Bombay by Theodore Cooke. The identified plant species were categorised as per habit, endemism (in Western Ghats and India), local rarity, presence in specific habitat (specialist[1] species) and IUCN (International Union for Conservation of Nature) status. The tree species were sorted as per their evergreen, deciduous and brevideciduous[2] nature while making the list. This species list was then used for further analysis.

Results and Discussion

The results of our species level survey are described and summarized below.

1. A total of 448 plant species were recorded within the Panshet Catchment which includes 131 species of trees, 75 species of shrubs, 70 species of climbers, 143 species of herbs, 23 species of grasses and 6 species of ferns.
2. A total of 100 families and 342 genera were recorded with the highest number of plants belonging to Leguminosae family followed by Poaceae and Apocynaceae families. The maximum number of species recorded belongs to Genus Ficus i.e. 11 species, followed by Genus *Acacia* and *Impatiens*.
3. The 448 plant species recorded include 425 native and 23 non-native species. The 425 native plant species include 74 endemic, 32 specialists, 21 locally rare and 3 IUCN listed species.
4. Among the 74 species of endemic plants, 13 are endemic to Western Ghats and 4 are endemic to Northern Western Ghats.
5. Table 1 shows the species diversity categorized on the criteria of endemism, habitat specialist/ locally rare, following IUCN status. There are some striking observations regarding species peculiarity or pattern of species distribution and status of vegetation cover. The observations throw some light on the distributed ecology of the vegetation in the catchment.
6. The Panshet catchment area is broadly composed of Grasslands, Tropical moist-deciduous forest, Tropical semi-evergreen forest and Broad-leaved valley or ravine forests (Gole P., Tetali P., 1985).
7. It was observed that the low rainfall zone holds more of moist deciduous vegetation with prevalence of grasslands and degraded areas. The grassland and degraded areas are dominated with Kusali grass (*Heteropogon contortus*) associated with some herbaceous growth.
8. Impact of human interference is more prevalent near the dam wall. Hence, a higher level of degradation is seen in this area.
9. The high and medium rainfall zones hold tropical semi evergreen vegetation. Original tropical semi evergreen forests are seen to be relatively in good condition in sacred groves, a few riparian patches, few government forest patches and certain privately owned protected patches.
10. Some plant species were observed only in high rainfall zone, which includes tree species viz *Cassine paniculata, Diospyros sylvatica, Neolitsea zeylanica, Holigarna grahamii, Symplocos racemosa* and *Trichilia connaroides*; Shrub species viz *Abutilon persicum, Glycosmis pentaphylla, Rauvolfia verticillata* and the climber *Toddalia asiatica*. Steep slopes in this area are dominated by Karvi (*Carvia callosa*).
11. In the high rainfall zone of the Panshet catchment, Kasa tree (*Elaeocarpus glandulosus*) is rarely found while it is seen commonly in high rainfall areas elsewhere, like Panchgani. However one huge old growth tree of this species, located in Dapsar Village (high rainfall) was observed during study.
12. Some floral species were found in both the high and medium rainfall zones. These include trees species viz *Aglaia lawii, Bombax insigne, Carallia brachiata, Celtis tetrandra, Ficus nervosa, Garcinia talbotii, Litsea ghatica, Memecylon talbotianum, Persea macrantha, Sapium insigne* and *Tetrameles nudiflora*. Shrub species of *Ixora nigricans, Maytenus rothiana, Nilgirianthus heyneanus* and *Thelepaepale ixiocephala* were found in these zones. Climbers found in these zones includes *Ancistrocladus heyneanus, Caesalpinia cucullata, Gnetum scandens, Pristimera grahamii, Argyreia involucrata, Clematis gouriana, Gymnema khandalense, Hoya wightii* and *Piper spp.*
13. In spite of heavy rainfall at the source of Ambi River, which is a crestline area of Western Ghats, comprised of cliffs and steep slopes, *Euphorbia* sp. was observed. It may be because of heavy rainfall causing soil erosion and physiological drought conditions on the rocky cliffs.
14. In the high rainfall area, the Ambi river hosts good riparian vegetation. The characteristics species of this zone are Umber (*Ficus racemosa*), Karanj (*Pongamia pinnata*) and Jambhul (*Syzygium cumini*) alongwith evergreen and brevi-deciduous tree species like *Chionanthus mala-elengi, Elaeocarpus glandulosus, Ficus hispida* etc.
15. Some species like *Litsea ghatica, Persea macrantha, Gymnema khandalens* were newly recorded as compared to the earlier survey of 1985.
16. An important highlight of this survey was the sighting of a climber, Ceropegia huberi. This is the first time it is being reported in the Panshet catchment. Its distribution is patchy and earlier it was reported only in Kolhapur (Gaganbawada), Ratnagiri (Amba Ghat), Satara (Vasota fort), and Pune (Tamhini). This species is endemic to Northern Western Ghats.

Table 1 : List of Endemic species of Panshet Catchment with IUCN status

Abbreviations and Terms :
E – Evergreen, D – Deciduous
BD – Brevideciduous
IUCN - International Union for Conservation of Nature
EN - Endangered; VU - Vulnerable
NT - Near Threatened; LC - Least Concern
S = Specialist species - Sensitive species requiring specific habitat. Such species may disappear if habitat is destroyed.
R = Rare species - Species rarely found in Panshet catchment

Sr. No.	Scientific name	Local name / Common name	E/D/ BD	S/R	Endemism	IUCN Status
	TREES					
1	*Actinodaphne angustifolia*	Pisa	E		Endemic to Western ghats	
2	*Aglaia lawii*	…	E		Endemic to Western ghats	
3	*Bombax insigne*	Devsavar	BD	R		
4	*Bridelia retusa*	Asana	BD		Endemic to India	
5	*Carallia brachiata*	Phanshi	E	R		
6	*Cassine paniculata*	Bhutya (Thikra)	E	S		
7	*Celtis tetrandra*	Brumaj	BD	R		
8	*Celtis timorensis*		BD	R		
9	*Dalbergia sissoo*	Sisoo	D			VU
10	*Dimocarpus longan*	Umb	E	S		
11	*Dimorphocalyx lawianus*	Jodpakli	E	S	Endemic to Western ghats	NT
12	*Diospyros sylvatica*		E	S		
13	*Elaeocarpus glandulosus*	Kasa	E	S		
14	*Ficus nervosa*	Loth	E	S		
15	*Flacourtia latifolia*	Taambat	D		Endemic to India	
16	*Garcinia talbotii*	Phansada	E	S	Endemic to Western ghats	
17	*Glochidion ellipticum*	Bhoma	E		Endemic to Western ghats	
18	*Holigarna grahamii*	Raan biba	E	S	Endemic to Western ghats	

Sr. No.	Scientific name	Local name / Common name	E/D/ BD	S/R	Endemism	IUCN Status
19	*Hymenodictyon obovatum*	Kadva sirid	BD		Endemic to India	
20	*Lagerstroemia microcarpa*	Nana	D		Endemic to India	
21	*Litsea ghatica*		E	S		
22	*Mallotus aureopunctatus*		E	S	Endemic to Western ghats	
23	*Memecylon talbotianum*		E	S	Endemic to Western ghats	
24	*Neolitsea zeylanica*		E	S		
25	*Persea macrantha*	Gulum	E	S		
26	*Phoenix loureiroi var. pedunculata/ Phoenix robusta*	Shelu	E	R	Endemic to India	
27	*Sapium insigne/ Falconeria insignis*	Hura	D			VU
28	*Sterculia guttata*	Kukar	BD	R		
29	*Symplocos racemosa*		E	S		
30	*Terminalia paniculata*	Kindal	BD		Endemic to India	
31	*Tetrameles nudiflora*		BD	R		
32	*Trichilia connaroides*	Limbara	E	R		
33	*Xylia xylocarpa*	Zambha	D	R		
	SHRUBS					
34	*Abutilon persicum*	Madam		R		
35	*Agrostistachys indica*	Agasti		R		
36	*Anisomeles heyneana*	Gopali			Endemic to India	
37	*Artemisia nilagirica*	Dhor Davana			Endemic to India	
38	*Cajanus lineatus*	Ran tur			Endemic to India	
39	*Calacanthus grandiflorus*			R	Endemic to India	
40	*Capparis parviflora*	Kabar		S		
41	*Carvia callosa/ Strobilanthes callosus*	Karwi			Endemic to India	
42	*Cissus woodrowii*	Girnul			Endemic to India	
43	*Desmodium laxiflorum*	Asud		R		

Sr. No.	Scientific name	Local name / Common name	E/D/ BD	S/R	Endemism	IUCN Status
44	*Ecbolium ligustrinum*	Hirvi aboli		R		
45	*Glycosmis pentaphylla*	Kirmira / Maenaki(Ban Limbu)		S	Endemic to India	
46	*Ixora brachiata*	Gorbale	E		Endemic to Western ghats	
47	*Ixora nigricans*			S		
48	*Maytenus rothiana/ Gymnosporia rothiana*	Bhalwand			Endemic to Western ghats	
49	*Nilgirianthus heyneanus*	Akra			Endemic to India	
50	*Rauvolfia verticillata*	Alpagandha		R		
51	*Thelepaepale ixiocephala*	Patri			Endemic to India	
52	*Calamus pseudotenuis*	Vet		S		
	HERBS					
53	*Adelocaryum coelestinum/ Paracaryopsis coelestina*	Nisurdi			Endemic to India	
54	*Aeginetia indica*			S		
55	*Aerides crispum / Aerides crispa*	Panshing		S	Endemic to Western ghats	
56	*Aerides maculosum*				Endemic to peninsular India	
57	*Asystasia dalzelliana*	Neelkanth			Endemic to India	
58	*Balanophora abbreviata*	Alimbi bandgul		S		
59	*Begonia crenata*	Kapru			Endemic to India	
60	*Chlorophytum glaucum*				Endemic to India	
61	*Crinum latifolium*	Gulabi karnaful		R		
62	*Crotalaria filipes var.filipes*	Phatphati			Endemic to India	
63	*Curcuma caulina / Hitchenia caulina*	Chavar		S	Endemic to Northern Western Ghats	
64	*Curcuma pseudomontana*	Raanhalad			Endemic to India	
65	*Cynarospermum asperrimum*	Dikna			Endemic to India	
66	*Desmodium ritchiei*				Endemic to India	
67	*Ensete superbum*	Rankeli			Endemic to India	
68	*Eranthemum roseum*	Dashmuli			Endemic to India	
69	*Eria dalzellii*			R	Endemic to Western Ghats	

Sr. No.	Scientific name	Local name / Common name	E/D/ BD	S/R	Endemism	IUCN Status
70	*Exacum lawii*	Lahan chirayat			Endemic to India	
71	*Exacum pumilum*	Jambhli chirayat			Endemic to India	
72	*Geissaspis tenella*	Lahan barki			Endemic to India	
73	*Habenaria grandifloriformis*				Endemic to Western Ghats	
74	*Habenaria longicorniculata*				Endemic to Peninsular India	
75	*Haplanthodes verticillatus*	Jakara			Endemic to India	
76	*Hemigraphis latebrosa*	Morpankhi			Endemic to India	
77	*Impatiens acaulis*				Endemic to India	
78	*Impatiens minor*				Endemic to India	
79	*Impatiens pulcherrima*	Dhal - Terda			Endemic to India	
80	*Kalanchoe olivacea*	Paanphuti			Endemic to India	
81	*Lavandula gibsonii*				Endemic to India	
82	*Malaxis rheedii*	Mala amri		S		
83	*Pecteilis gigantea*	Waghchora		S		
84	*Phyllocephalum tenue*	Parnagumphi			Endemic to India	
85	*Pimpinella adscendens*				Endemic to India	
86	Pinda concanensis	Panda/Pinda			Endemic to Northern Western Ghats	
87	*Rhamphicarpa fistulosa / R. longiflora*	Tutari			Endemic to India	
88	*Senecio bombayensis*	Sonki			Endemic to India	
89	*Smithia bigemina*	Kawla			Endemic to India	
90	*Smithia hirsuta*				Endemic to India	
91	*Smithia purpurea*	Barka			Endemic to India	
92	*Swertia minor*				Endemic to India	
93	*Tectaria cicutaria*	Kombadnakhi		R		
94	*Trachyspermum roxburghianum*	Pinela			Endemic to India	
95	*Zingiber neesanum*	Nisam			Endemic to India	
	CLIMBERS					
96	*Ancistrocladus heyneanus*	Kardal		S	Endemic to India	
97	*Dalbergia horrida var. horrida*	Pedgul			Endemic to India	

Sr. No.	Scientific name	Local name / Common name	E/D/ BD	S/R	Endemism	IUCN Status
98	*Caesalpinia cucullata*	Ragi		R		
99	*Gnetum scandens*	Umbli		S		
100	*Pristimera grahamii / Hippocratea grahamii*	Lokhandi/daushir		S		
101	*Argyreia involucrata*				Endemic to India	
102	*Argyreia sericea*	Gavel			Endemic to India	
103	*Asparagus racemosus*	Shatavari			Endemic to India	
104	*Ceropegia huberi*				Endemic to northern Western Ghats	
105	*Ceropegia oculata*	Mor kharchudi			Endemic to India	
106	*Clematis heynei*	Raanjai			Endemic to India	
107	*Cynanchum tunicatum*	Panchali		R		
108	*Dioscorea belophylla*			R	Endemic to India	
109	*Entada rheedii*	Garambi		S		
110	*Gymnema khandalense/ Bidaria khandalense*			S	Endemic to Northern Western Ghats	
111	*Hoya wightii*	Ambari		S	Endemic to India	
112	*Jasminum malabaricum*	Kusar			Endemic to India	
113	*Piper spp.*			S		
114	*Toddalia asiatica*	Jungli mirchi		S		

Note: Above list is a result of 6 months survey and more species may get recorded with a detailed multi-season survey.

Table 2 : Floral composition observed in rainfall zones

Rainfall Zone	Average annual rainfall	Floral Composition
Low	2000 to 3000 mm	Terminalia- Bridelia – Mangifera
Medium	3000 to 6000 mm	Actinodaphne –Terminalia- Albizia
High	6000 to 9000 mm	Memecylon- Olea- Syzygium

Note: This composition is as per the data collection and observations done by the team in catchment. Quadrat sampling was not done.

Table 3- Distribution of sacred groves in rainfall zones

Low rainfall zone	Medium rainfall Zone	High Rainfall Zone
1. Viroba SG, Ambegaon 2. Bhairi SG, Ambegaon 3. Talawati SG, Ambegaon 4. Pandharphali SG, Vanjarwadi 5. Kalkai SG, Vanjarwadi 6. Kalkai SG, Giwashi 7. Jagoba SG, Giwashi	1. Vardaini SG, Gondekhal 2. Somjai SG, Gondekhal 3. Janani SG, Mangaon 4. Shirkai SG, Shirkoli	1. Unnamed SG, Kurtawadi 2. Vardaini SG, Kurtawadi 3. Jakhin and Kalkai SG, Dapsar 4. Kuthar SG, Dapsar 5. Shambhoji SG, Dapsar 6. Somjai SG, Dapsar 7. Mulai SG, Dapsar 8. Kalkai SG, Tekpovale 9. Vardaini SG, Tekpovale

Note: SG – Sacred Grove

17. The whole catchment area is dotted with sacred groves. They differ in size. The highest number of sacred groves was observed in high rainfall zone. The Mangaon Sacred Grove in medium rainfall zone is the largest sacred grove with an area of about 16 ha. (Table 3)
18. People cultivate *Dendrocalamus* species of Bamboo around their villages for economic reasons (Gole P., Tetali P., 1985). A naturally growing bamboo species, Kalak (*Bambusa arundinacea*) was observed in the high rainfall zone.
19. Inspite of the timber value, the locals preserved mango trees since the fruits offer sustainable income for them. Due to this, the dominant vegetation in the low and medium rainfall zones consists of mango trees.
20. In the high rainfall zone, one of the characteristic components of vegetation is Lianas. Species like Umbali (*Gnetum scandens*), Kardal (*Ancistrocladus heyneanus*), Watoli (*Diploclisia glaucescens*), along with Garambi (*Entada rheedii*) were found in good canopy patches.
21. Liana of Garambi (*Entada rheedii*) is found throughout the catchment. In the low rainfall zone, it is found only in sacred groves, probably because of suitable conditions of moisture. In the high rainfall zone, it is more common and found even along the roads, covering trees and creating dense canopy.
22. Relative to 1985, shifting cultivation practices have now declined. The abandoned shifting cultivation patches are now covered with dense shrubbery and show growth of woody and hardy species like Karwand (*Carissa congesta*), Dhayati (*Woodfordia fruticosa*) along with tree species like Ain (*Terminalia tomentosa*), Kumbha (*Careya arborea*), Asana (*Bridelia retusa*) etc. Good regeneration of plant species was observed in all three rainfall zones.
23. Plantations of non-native species like Gliricidia and Australian Acacia were observed on large scale in the vicinity of the dam wall, near the reservoir and on hill slopes throughout the catchment.
24. Wild vegetation provides food for local people e.g. Kartoli (*Momordica dioica*), Takala (*Cassia tora*), Kurdu (*Celosia argentea*) and fruits of Karvanda (*Carissa congesta*), Alu (*Meyna laxiflora*), Mango (*Mangifera indica*) etc.
25. Presence of weeds was very common along the roads, fringe areas of sacred groves, open areas, periphery of agricultural land and settlements. Invasive species like *Cosmos, Eupatorium, Parthenium, Alternanthera, Lantana* etc. were found throughout the catchment.

Conclusions

1. The occurrence of some specialist plants in dense vegetation patches outside sacred groves highlights the need of conserving these vegetation patches for conservation of catchment area vegetation and maintaining habitat continuity in the area.
2. The sacred groves harbor higher number of specialist and endemic species and need to be conserved with high priority.
3. Even in the low rainfall zone, if protection is provided, species like *Ceropegia bulbosa* and *Ceropegia oculata* are seen regenerating. This observation was made in the plot where Ecological

Representative Photographs of Survey areas and plant species

Ceropegia huberi, climber endemic to Northern Western Ghats

Habenaria longicorniculata

Holigarna grahamii (Ran bibba), tree found only in high rainfall zone

Ceropegia occulata

Symplocos racemosa, tree found only in high rainfall zone

Dimorphocalyx lawianus (Jodpakali), tree endemic to Western Ghats

Open grassland in Ambegaon Khurd village

Kuthar sacred grove

Shrubbery

Tall canopy

Society has carried out ecological restoration for the past several years.

4. The previous ecological survey of Ecological Society pertaining to the Panshet catchment dates back to 1985 i.e. more than 30 years ago. The present detailed survey was conducted in 2014, though only for six months; therefore the extensive survey and further studies of the vegetation in Panshet catchment are needed.
5. Looking at the vegetation composition of mature forest including sacred groves, high endemism was observed in the high rainfall zone near crestline. Several streams and river Ambi originate in this area. Therefore this area has a high conservation value.
6. There is an urgent need to protect the following rare and specialist species otherwise they will become locally extinct due to continued degradation and land use change : *Ancistrocladus heyneanus, Ceropegia huberi, Elaeocarpus glandulosus, Garcinia talbotii, Cassine paniculata* etc.
7. The association between flora and fauna highlights the importance of preserving various types of forests. e.g. The Malabar Giant Squirrel is associated with continuous canopy seen in sacred groves.
8. There are several threats to sacred groves like cattle grazing, tree cutting, transport through grove, temple construction inside the grove, road construction, presence of adjacent private land and construction projects coming up in vicinity etc. Sacred groves being old mature forests of great biological value, these issues must be prioritised.

References

An Enquiry into the Status of animal and plant life in critical areas of Western Ghats in order to evolve plan to conserve their biological diversity, Ecological Society, Pune, Vol I and II, 1985.

Report of Ecological Survey undertaken in Panshet Catchment and Bhimashankar Wildlife Sanctuary under Small Grants Program, Global Forest Watch, Ecological Society, Pune, India, April 10, 2015.

The Sacred Groves of Western Ghats in India, Gadgil M. and Vartak V., Economic Botany, 1976.

Changes in Ecological Landscape Pattern and Land Use from 1985 to 2014 in the Panshet Dam Catchment, Karandikar M., Dumale V., Deshpande S., Journal of Ecological Society, Volume 28, 2015.

Management of Forests in Northern Western Ghats, Ghate K., Journal of Ecological Society, Volume 26 – 27, 2014.

Flora of Maharashtra State (Dicotyledones), Volume 1, Editors N. P. Singh, S. Karthikeyan, P. Lakshminarasimhan and P. V. Prasanna, Botanical Survey of India, 2000

Flora of Maharashtra State (Dicotyledones), Volume 2, Editors N. P. Singh, P. Lakshminarasimhan, S. Karthikeyan and P. V. Prasanna, Botanical Survey of India, 2001

Endemic and Threatened Flowering Plants of Maharashtra, Dipak Kumar Mishra and N. P. Singh, Botanical Survey of India, 2001

The IUCN Red List of Threatened Species. Version 2014.3. <www.iucnredlist.org>. Downloaded on 31 January 2015.)

http://wgbis.ces.iisc.ernet.in/biodiversity/database_new/?q=node/35

http://www.ifpindia.org/content/mapping-tree-endemism-western-ghats

Endnotes

1. Specialist species is a species having specific habitat requirement and it occurs as remnant of original (primary) forest, whereas generalist species can occupy a variety of habitats including degraded.
2. Brevideciduous trees show brief loss of leaves just prior to flowering or before new leaf growth.

Restoration Templates for Sahyadri (Northern Western Ghats)

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Abstract

Sahyadri mountains are witnessing a great change in land use pattern and lifestyle of local people over the last few decades because of modern development and construction of dams. As a result ecological systems within the catchment have changed resulting in a change in socio-economic conditions. The usual approach to tackle this situation is plantation or afforestation. However, this approach does not consider the revival of ecosystems. As mitigation measures, the Ecological Society, in 1986, had conducted experiments in the Panshet dam catchment. This resulted in the development of restoration methods for the bioclimatic region of Sahyadri. The approach of this experiment was using a low-cost restoration methodology. In this, enhancement of the ecosystem in early stages of restoration provides ecosystem services and products, such as fodder in the intermediate stage to the local communities. By using similar techniques, oikos for ecological services, a company engaged in ecological restoration, undertook several ecological restoration programs on private lands within the Sahyadri region. The results showed significant improvement in ecosystems and biodiversity, thereby improving livelihood options for the local communities.

Funded by a grant from Global Forest Watch, Ecological Society conducted an assessment of changes in land use and status of biodiversity in Panshet, in 2014-15. The Panshet dam catchment forms a part of Sahyadri and similar conditions are encountered elsewhere in the region. This study made an assessment of the potential for restoration in the catchment area. Based on this study and earlier studies by oikos for ecological services, we created templates which are intended to guide restoration process of degraded lands in Sahyadri.

The templates are backed by the experience of actual implementation of restoration techniques on various land patches within Sahyadri during the last 30 years. Three templates are presented to guide the complete process of restoration.

Keywords: *Ecological restoration, Restoration templates, Sahyadri, Northern Western Ghats.*

Introduction

Under undisturbed conditions, the physiography and climate of the Northern Western Ghats, locally known as the Sahyadri mountains, should support a tropical semi evergreen forest on the crest line and a moist deciduous forest on its eastern spurs in the 'climax' state of vegetation (Champion and Seth, 1968). However, the present condition of these forests is variedly degraded and fragmented due to human use for cultivation, commercial gains, dams. For example, in the case of Panshet dam near Pune, there are significant changes in the river basin and in community use of the available resources, because of the construction of the Panshet dam. The villages in the catchment area have been shifted to higher contours, where they practice slash and burn farming (Gole, 1985). This type of shifting cultivation has turned all the forested slopes to secondary vegetation. Moreover, contractors who buy timber from the local people either for making coal or selling as timber, have triggered the clearing of forested slopes in this region. In the last few years' farm house townships have attracted urban attention and this has put severe

pressure on the natural setting of the catchment. By extensive use of earth moving equipment, the land use has changed rapidly and further degraded the landscape. The present state of the landscape of Western Ghats is the outcome of years of use by local people and the modern developmental pressures within the last few decades (Ghate, 2014). The original forest cover and biodiversity of the NWG, now remains only in some pockets of notified protected areas and within semi-protected areas like sacred groves. The rest of the landscape is degraded to various seral stages depending on the degree of disturbance, mainly due to socio-economic changes in the catchment (Ghate, 2014). Therefore, there is an immediate need to conserve and restore these ecosystems towards better health of the landscape benefitting human as well as non-human beings.

As a solution to address this degradation, efforts are usually put in plantation or afforestation to increase biotic resources needed by the local community and to improve ecosystem. However, plantations cannot be affordable and feasible over a large expanse like the NWG. Moreover, plantations do not consider a landscape approach nor the revival of ecosystems. Plantations are effective when undertaken on smaller areas where the landscape is in a degraded state. Ecological society has developed restoration methods where low cost passive restoration techniques can be employed. This requires protection of the area and undertaking certain interventions. These are planned for ecological restoration at a landscape level. During this experimentation, Ecological Society (ES) has developed a framework for restoration.

During any restoration project, especially in the Northern Western Ghats (NWG) some important aspects must be considered. These are (i) 'fragility of ecosystem' due to very high rainfall along the crest line (ii) catchment of some of the major rivers in the Indian peninsula (iii) physical conditions (abiotic conditions) and forests (biotic resources) at the river source regions (iv) these are the major soil producing areas, supplying soil downstream. All these special physical features have created unique habitats which have been supporting biodiversity some of which are unique to the habitat, that is endemic species. In this situation, the biodiversity and ecosystems are extremely important and precious. (Ghate, 2014)

Background

The restoration templates are intended to offer a process guide to help users plan and take decisions based on the collected data. Moreover, they also specify what data needs to be collected. For a given bioclimatic region, restoration techniques may remain fairly similar. The actual process of nature restoration involves a trial and error approach. Thus, learning from earlier restoration experiments may help to follow process of restoration.

These templates are developed based on experimentations conducted in 30 long years, starting with an assessment of biodiversity of Panshet Catchment, in 1985. This survey showed a deficient resource situation in this region. Due to the dam construction, several villages were displaced to higher contours. Thus, the villagers had poor access to water and got less fertile land for cultivation and consequently faced livelihood issues. Earlier, their lifestyle was dependent on natural resources, but as the forests degraded, bio-resources grew scarce in the changed situation. In 1986, ES undertook an experiment on a barren hill slope owned by the Irrigation department, Maharashtra State. A three-year restoration exercise was initiated at this site. The idea of creating templates originated in this experiment. Subsequently, the experience gained from projects carried out by oikos for ecological services at others sites in the NWG and other bioclimatic zones of India, helped shape the templates. The templates have been benefited from the insights gained in the ongoing project within Koyna catchment in NWG, since the last 10 years. This project is a pure conservation approach towards restoration. Similarly, oikos undertook restoration planning for 16 sacred groves in Palghar district (earlier Thane district) where, actual implementation was done in two sacred groves over three years. The community was involved in the restoration. Over the last 15 years, oikos has applied restoration principles in over 100 commercial projects. For example, in an eco resort on 300 acre near Bangalore more than 70 % of the land is dedicated for conservation and restoration. This experience and observations of various ecosystem stages at landscape level over the years has helped in the making of templates proposed herewith. We expect these templates to help in identifying problems, collecting right data, following the right procedures and consequently save time and inputs to restoration practitioners. They can be used to assess current conditions before making a choice of appropriate restoration technique. The templates can be used for restoration work in bioclimatic zones similar to that of Sahyadri.

After a review of literature available on restoration templates and discussions with experts, it was seen that most of the existing templates have evolved for

watershed development or stream restoration (Dept of Environmental Protection, 2004). Moreover, in many of the templates, the focus is to restore physical attributes, control erosion, or stop pollution. It was also seen that the templates lacked the consideration of biotic components in them. Our experience suggests that biodiversity can be used as an indicator to judge the present state of the land and then design a restoration strategy. Thus, our approach towards restoration starts with an assessment of physical conditions and biotic components. This article describes the templates and explains their use.

The Society for Ecological Restoration (SER) USA, an organization promoting ecological restoration, has developed a set of guidelines for developing and managing ecological restoration projects. The first edition discusses various terms used in restoration ecology, importance of assessing reference ecosystems and non-native species along with guidelines to set restoration objectives and design planning (Science and Policy Working Group , 2004). The second edition focuses on planning and implementation tasks. SER suggests preliminary tasks like appointment of a restoration practitioner and a team, documentation of history of the site, establish reference ecosystem, defining goals and liasoning with public agencies. Implementation planning and tasks include description of each intervention, scheduling, marking boundaries, installing permanent fixtures followed by post-implementation tasks for effective monitoring and evaluation of the project (Clevell, Rieger, and Munro, 2005). These guidelines seem to be useful in technical planning of the project but do not provide restoration activities.

Restoration potential analysis

Before undertaking any restoration program, it is important to assess the restoration potential of the area surrounding the selected site. This is because the site is connected to a larger landscape through flows of surface and ground water, exchange of nutrition, seeds and through wind and water and movement of fauna. The restoration potential analysis conducted in the Panshet dam catchment in the NWG is discussed ahead.

Restoration potential analysis for Panshet catchment: A Case study

For undertaking an assessment of the restoration potential, the following steps were taken.

1. A satellite image of the selected area was used to examine the land use and assess the vegetation.
2. The identified land use and vegetation was divided into classes and a map was prepared from this.
3. To validate these classes and locations, ground truthing was undertaken in sample areas.
4. The quality of the vegetation classes was decided by the species composition and the occurrence of endemic species or habitat specialist or locally rare species. This established the level of degradation and the potential for restoration in this area.

Based on the above analysis, the restoration was prioritized into four categories.

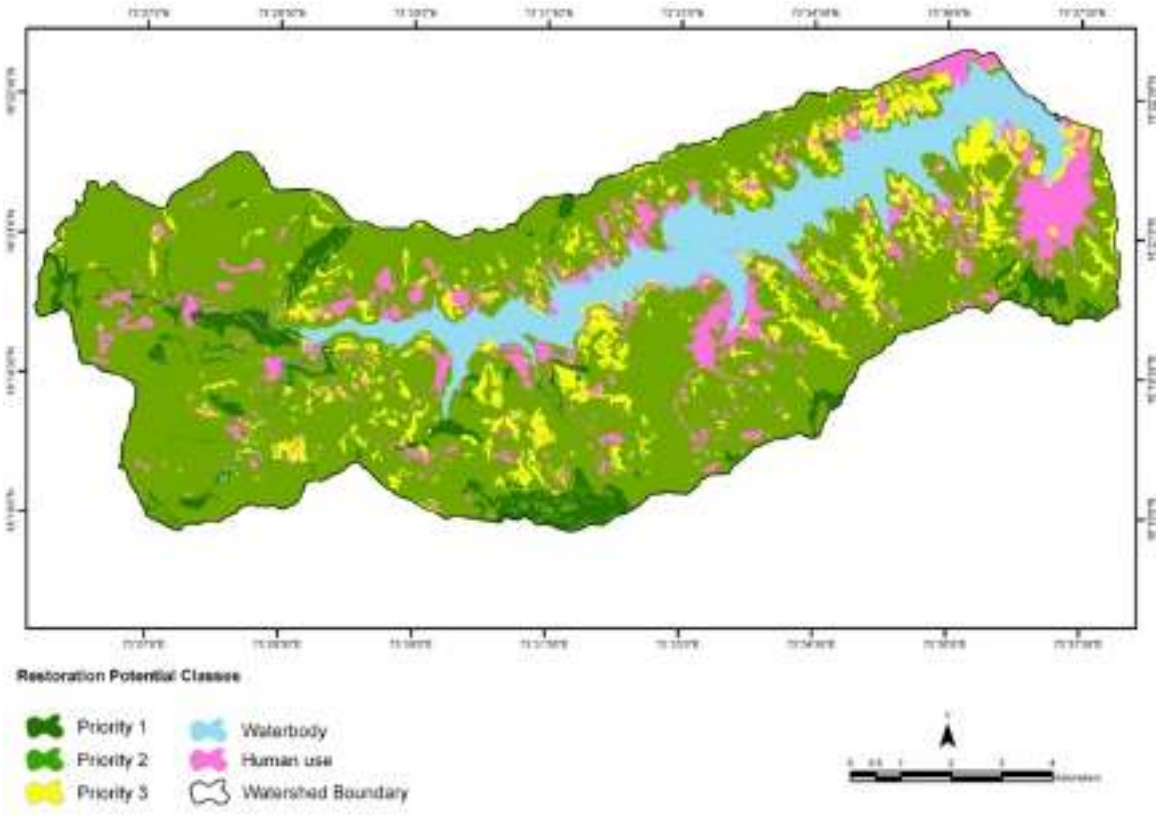
No	Restoration Priority	Vegetation class	Area	%
1	Priority 1	Mature forest	2922.10	11
2	Priority 2	a.Dwarf canopy	10113.36	40
		b.Scrub	6427.13	25
3	Priority 3	Open grasslands	3268.13	12
4	Priority 4	Human use	3027.16	12
		Total	25757.88	100

The table shows priorities towards conservation and restoration. Mature forests which have endemic biodiversity are the first priority for conservation. These include all sacred groves and some inaccessible areas. If not fully protected, species within these areas may get wiped out from the entire catchment.

The map shows that there are three major vegetation classes in the catchment. These classes are defined on vegetation character indicating degrees of degradation. There is a potential for restoration in vegetation class with the second priority. These are degraded forests but can be improved relatively fast. In the Panshet catchment, remnants of earlier forests are still seen sporadically. Root stock in such areas help in faster restoration than totally barren areas or grasslands.

Grasslands being a totally different habitat than forests, will take longer time to restore. Also are assigned a lesser priority for restoration as forest endemic species are already lost from these areas.

Finally, though it appears that land under human use is minimal, there is substantial use of the land around these areas for activities such as grazing, fuel wood and shifting cultivation. Mature forest areas like Sacred Groves are also threatened due to developmental activities around them and human interventions inside grove. Also, practices like lighting fires, put severe stress on the landscape. Similarly, the



potential future threats of new settlements owned by urban people like farm houses are visible in the map, must be considered. Hill slopes are fenced, leveled and plotted for modern development. All these land classes can be restored by using restoration techniques discussed below.

Restoration template

The entire Sahyadri has composition and landscape similar to Panshet dam catchment, therefore we have used this study as a canvas to propose restoration template for entire region. Based on experimentation carried out over the years, Ecological Society has suggested restoration techniques which can be used to restore this variedly degraded landscape. The concept of nature restoration is now gaining popularity and its benefits are tangible. Thus, the authors propose templates in this paper which can be used by various stakeholders. These templates comprise restoration techniques as illustrated further in a Table 1. However, the techniques need to change as per the starting point or site specific conditions or current status of the land under consideration.

These templates are designed using two approaches:

1. Pure conservation approach where efforts are directed towards restoration of climax forest, for the sole purpose of restoring natural resources, biodiversity and ecosystem services. Refer Table 2. Various stakeholders like government departments like forest and irrigation departments, village commons, private parties and others can consider this approach. Government departments can implement this for land owned by the forest department, lands considered for compensatory afforestation programmes or the land which is going to be unused for next few decades. Local farmers may not use this approach but urban citizens owning farm house plots would find this approach useful, since they are not dependent on land for their livelihood. With this approach, they can give back to nature. To a certain extent, a part of village common land can be restored with this approach considering long term benefits and ecosystem services being offered to future generations in terms of water or fertility of soil, or pollinating services etc.
2. Integrated approach: Restoration to strengthen natural resources to support livelihood of local people. Refer Table 3. This approach is intended

Table 1 : Steps in Restoration

No.	Restoration technique	Details
1	Protection	Total protection from cutting of vegetation, cattle and fire is the first step. The same can be achieved with dry fence and live hedge. Identification and protection of safe sites.  
2	Soil and moisture conservation	Erosion-prone areas or slopes needs to be worked on with the help of local materials like stones and boulders to arrest soil and reduce water velocity.   
3	Vegetation management	Protection to existing flora, stage wise natives plantation (initially hardy plants and then desired plants), removal of invasive non-natives etc.  
4	Habitat creation	Creation of rock piles, log piles, wetlands, plantation of larval host plants, shrub clusters etc.  
5	Plantation (Native plants)	Selecting appropriate native plants as per the current status of the soil and land.
6	Seed dispersal (Native plants)	One of the easiest ways to introduce native plants and test regenerating capacity of the soil.

** Photographs: oikos for Ecological Services*

Table 2 : Conservation approach

Current status of land →	**Grasslands**	**Scrub canopy**	**Shrubbery canopy**	**Dwarf forest**	**Tall**	**Mature**	End point : Semi-evergreen Forest
Restoration techniques	1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5, 6	1, 3, 5, 6	1, 5, 6	1, 5, 6		
Approximate time frame (yrs)	15 - 20	10 – 12	10 - 15	10 - 15	20 - 50		

** Please note: The time frame is based on observations of local people and team along with the restoration experiment carried out by Ecological Society at Panshet catchment. It is subject to variation.*

*** Treatment to a special habitat in Sahyadri: 'Rocky outcrop' Habitat: Sahyadri have a special type of rocky habitats shaped due to Lateritic outcrop or Basalt outcrop. Here, scarcity of soil and harsh physical conditions lead to formation of vegetation community dominated by grasses and herbaceous flora along with habitat-specialist amphibians and reptiles (Watve, 2010). These being very special ecosystems and host special endemic species. Therefore they must be protected completely from any human interference. Considering the high degree of endemism in biodiversity, it is suggested to have no intervention on this land class. Using the first technique in table 1, i.e. protection is recommended and plantations or using other restoration techniques are not recommended in this habitat.*

**** Special Sites : Existing patches of Protected Mature forests also should be excluded from any interference and be treated as special sites. These may include sacred groves, inaccessible areas, rock fall areas, few government owned mature forest patches etc. All such sites need just first technique i.e. protection as in table 1. But if at all any kind of interference or degradation is seen, appropriate measures to be selected based on above template.*

Table 3 : Integrated approach

No.	**Restoration technique**	**Starting point**		
		Grasslands	**Scrub**	**Dwarf Canopy**
		Management for fodder		**Management for fuel wood**
1	Protection	✓	✓	✓
2	Soil and moisture conservation	✓	✓	
3	Vegetation management	✓	✓	
4	Habitat creation	✓	✓	✓
5	Plantation			✓
		End point : Livelihood support		

**This approach does not include Tall or Mature Canopy forest patches as such patches have to be protected and conserved as it is.*

to address needs of local people living in these mountains for generations and use the local resources for their livelihood. When the population was lower, resources were enough to suffice their needs and they could survive without land management. But the increasing population, changing life style and resources depletion, there is an immediate need for land management and nature restoration, so that they can be used sustainably in future. In this approach, the objective is to improve landscape and maintain it in a better condition so that communities will get benefits of from the various ecosystem services and products.

In both the templates, operational techniques remain the same.

Restoration template for data monitoring useful for Implementation

Measuring the key indicators mentioned below will help track the path of the restoration effort. Often the direction of restoration may be subject to nature's vagaries, local climatic effects, and impacts of human interference. Monitoring these indicators will help in judging the interventions needed to keep restoration on the desired path.

Additional Tips for Ecological Restoration (Gole, Restoration of Nature, 2007)

- When the work of ecological restoration begins on a given area, total protection is the key factor and local community awareness regarding this initiative is also important.
- A detailed survey of the existing floral and faunal species and its documentation is necessary. It is useful as base line data during future stages of restoration.
- Identification of reference sites like Sacred Grove or mature forest patch nearby the project area will help in understanding composition of climax stage

	Indicator	**Details**	**Year wise data**		
			Year 1	**Year 2**	**Year 3**
A	**Biomass**				
	Increase in biomass	Dry and wet biomass of grasses			
B	**Overall biodiversity**				
	Increase in habitat diversity	Grassy areas : Shrub Clusters : Tree clusters : Instream habitats* : Wetlands			
	Index of diversity - June	Number (flora-fauna species) to be recorded from each habitat			
	Index of diversity - September	Number (flora-fauna species) to be recorded from each habitat			
	Improvement in biodiversity	Ratio of 'Species indicating degradation : Species indicating improvement'			
C	**Soil and moisture conservation**				
	Soil quantity arrested				
	Soil pH				
	Soil temperatures				
	Soil carbon				
	Water recharge capacity				
	Conductivity				
	Moisture monitoring	Thrice a year			

	Indicator	Details	Year wise data		
			Year 1	Year 2	Year 3
D	Vegetation				
	Change in % of cover types	Ratio of No-vegetation : grass : shrub : tree			
	Revival of shrubs	Average height and width of monitored clumps			
	Natural regeneration	Number and species of regenerated saplings within quadrats			
	Increase in herbaceous flora	Species and Status : Common, Few, Rare			
	Change in Grass community	Composition of grasses, % area covered by each species			
	Overall plant list				
	Survival of saplings during dry season and their height.	Lists along with numbers			
E	Habitat Improvement				
	Safe site development	Safe sites for special plant, Nesting of birds, Webs of spiders, insect diversity and population etc. : Lists of species and numbers within quadrats			
	Improvement in microclimate	Ambient Temp and humidity readings : Open areas and Shady areas			
	Associations	Plants : Plants Flora : Fauna e.g. Butterflies – Foodplants			
	Habitat interactions	Habitat listing and observing interactions within habitats. e.g. wetland and nearby shrubbery			
F	Map of project land				

* *Instream habitats like pools, riffles, bars etc.*

ecosystem and developing seed bank of native plant species.

- Removal of any kind of pre-existing native vegetation is not advised. Whatever vegetation cover exists is useful for conserving moisture as it adds biomass and casts shade.
- When it comes to removal of non-natives, experts should be involved.
- In the application of restoration techniques, if biomass is externally added to the site - documentation of observations regarding species growing on such area is necessary. It will help in deciding repetition of such intervention.
- If possible, create small wetlands/ponds in the area as it will add to the habitat diversity. It will help improving the micro climate.

- One can plan to have habitat diversity in the given area; e.g. Patch of scrub and grassland and clumps of trees, etc. In case of wetlands, shallow sheet of water, sand flats, islands, dykes can be considered. This will help in increasing biodiversity.
- Documentation of special observations is necessary to understand the trend of the restoration stages. e.g. Excessive growth of certain herbs along the path or hedges indicating disturbances to some extent, occurrence of specialist species, flocks of certain species of bugs and beetles.

Limitations of the template :

1. The templates proposed may not be enough for a completely changed land use or degraded landscape like mining areas where hardly any mosaic of habitat is retained. In such a case, simple protection and creation of physical features may not get quick results in revival of biodiversity. Here active restoration techniques are recommended, where use of external materials and energy is involved. We recommend one important active technique of addition of biomass to the land so that soil processes can be initiated along with other techniques mentioned in the template like creation of ponds and introduction aquatic plants etc.
2. The same strategy can be applied where grasslands stage is arrested due to edaphic factors. Due to degradation, soil loss is so heavy that rocks get exposed and so no biomass is available as a raw material for restoration calling for active restoration techniques.

Significance of restoration templates

The above restoration templates may help various stakeholders like forest department, irrigation department, or private land owners who own large land parcels in Sahyadri. Often, these land parcels can be ecologically improved, but are neglected due to lack of awareness and knowledge of restoration techniques. With the help of clear understanding of current status and using these restoration templates, it is possible to undertake planning and implementation of restoration. However, we suggest involving experienced ecologists for planning and execution.

These templates would be useful for large scale restoration of fragmented landscapes which need to be preserved for their ecosystem services. For example, Sahyadri mountains are source regions for many rivers supplying water to the Indian peninsula, and therefore needs to be preserved for sustainable use.

Institutes like World Resources Institute (WRI) and Global Forest Watch (GFW) are working towards restoration at landscape level. In the last few years, several countries have been undertaking restoration of deforested and degraded forest landscapes in their own countries. The global Bonn Challenge, launched in 2011, calls for the restoration of 150 million hectares by 2020. As a response to this, WRI, International Union for Conservation of Nature (IUCN) and the University of Maryland created an Atlas of Forest Landscape Restoration Opportunities. This is a coarse-scale map of the potential forest restoration opportunities globally.

Restoration is expected to create significant employment opportunities at local scale in tropical countries like India. Considering the paucity of information and methodologies available for restoration, the authors expect that the templates suggested here would be of practical use. The authors acknowledge the scope for improvement of these templates and invite practitioners to use them and provide feedback.

References

Champion, H. G., and Seth, S. K. (1968). *A revised survey of Forest types on India*. Govt of India Press.

Clevell, A., Rieger, J., and Munro, J. (2005). *Guidelines for developing and managing ecological restoration project*, 2nd Edition.

Dept of Environmental Protection. (2004). *The watershed restoration template*. Pennsylvania Department of Environmental Protection and the Canaan Valley.

Ghate, K. (2014). Management of forests in Northern Wetsren Ghats. *Journal of ecological Society, Vol. 26-27*.

Gole, P. (1985). *An Enquiry into the status of animal and plant life in critical areas of Western Ghats in order to evolve a plan to conserve their biological diversity*. Ecological Society.

Gole, P. (2007). *Restoration of Nature*. Ecological Society.

(2015). Report of *Ecological Survey undertaken in Panshet Catchment under Small Grants Program (Global Forest Watch)*. Ecological Society.

(2004). *SER International Primer on Ecological Restoration, Science and Policy Working Group (Version 2)*. Society for ecological Restoration.

Watve, A. (2010). *Rocky Plateaus*. WGEEP.

Reprint and Analysis of ``The Rio Conference : Some Bare Truths'' from Vol. 6

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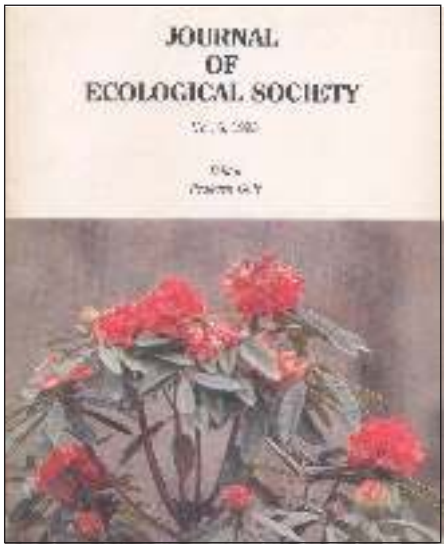
We re-print a note, "The Rio Conference: Some Bare Truths" by Prof. Prakash Gole, which appeared in vol. 6 (1993) of this journal, along with an analysis as to where the global community stands on environmental justice and equity 25 years later.

Journal of Ecological Society, Vo. 6, 1993

The Rio Conference : Some Bare Truths

Prakash Gole



For environmentalists all over the world 1992 proved memorable as it saw their largest gathering ever for the global conference on environment held at Rio De Janero in Brazil. India had sent a strong delegation and a number of our eminent environmentalists attended it as representatives of NGOs. Anil Agarwal and Sunita Narayan of Centre for Science and Environment, New Delhi, had circulated a draft statement on Global Environmental Democracy for comments which they presented to the conference.

Everybody now knows what the global conference achieved or failed to achieve. The issues raised, discussed, shelved or thrown overboard by the conference concern everyone living on this planet: human as well as non-human being alike. It is in this context our comments on Global Environmental Democracy appear to be relevant. They are reproduced below. (Editor)

Dear Anil Agarwal, Sunita Narayan and others

Once again I must congratulate you for bringing out a concise, logically argued draft statement on Global Environmental Democracy. I commend your optimism and am in agreement with the basic position taken on the need to formulate a global programme to provide jobs to generate ecological regeneration and restoration and the need to compensate South adequately for their store of germplasm and biodiversity that their traditional practices have helped to preserve.

In some respects however, I find the position taken by you to be too optimistic or too simplified.

With the cessation of cold war and the nations of eastern Europe, the erstwhile USSR and even China now joining the North (USA, W. Europe and the Antipodes), the North is more likely to impose its

viewpoint on the South than agree to any sharing of the burden. The annihilation of Iraq should serve as a warning that whenever necessary brute force will be used. Any talk of the South demanding compensatory payment from the North for its errant behaviour appears to me a bit unrealistic. I do not believe that North will consider it its moral responsibility to provide a lead that gives confidence to the South, instead a new colonialism is likely to emerge.

The only way to bring the North to the negotiating table on an equal footing is to deny them the vast markets that the South provides for their products. The nations of the South must unite to tell them that they do not want the destructive technology: machines, chemicals and weapons produced by the North nor are they interested in selling their raw materials to the North. Their own technology and production system by using their own skills, brain power and materials, are fully capable of satisfying their wants. I have no doubt this alternative technology is possible and is realistic.

Achieving this unanimity among the South is obviously a tall order. As long as this unity and confidence cannot be achieved by the South its bargaining position will continue to be extremely weak.

In your Elements of Global Environmental Democracy a great stress has been laid on participatory community institutions. I find that our environmentalists are greatly swayed by a few successful experiments carried out in our country in that direction. That they are not copied generally is because they demand complex social and legal changes as you have stated. Apart from this I may draw your attention to the north- south divide that exists in each developing country. I am referring to the city and countryside divide (India and Bharat).

Our whole development in the last 40 years has been city oriented. The average city- dweller enjoys a far higher standard of living than even a rural rich. City- life is heavily subsidised at the expense of the countryside. Now if village institutions are strengthened, it will result in the diversion of resources away from the cities. Any fall in the living standards of the city – dwellers will be resisted by our elite which includes all our social leaders, politicians and bureaucrats.

I believe that if village institutions are strengthened, become fully democratic and are headed by well-trained, skilled rural leaders, they will definitely lower the disparity between cities and rural areas given the existing technology. It will not however, be tolerated by our elite.

The bargaining position of the South is weak because the elite in the South take pride in slavishly aping the North.

You have insisted upon a global right to survival for all human beings. Why not extend this right to the non-human beings also? I find that all environmentalists dither on this particular point.

You feel that the vast numbers of unemployed and underemployed in the South can gain employment through a massive global initiative for ecological regeneration. It is however, not enough to provide a survival wage; it is also necessary to ensure better prospects for the future. This can only be possible if almost each manual labourer acquires a definite skill and takes pride in his work. This aspect is utterly neglected in our educational system. Environmentalists should not take the elitist position that only a survival wage is enough to ensure satisfaction and dignity to a manual labourer.

I also do not agree that this massive employment programme should be financed through a Planet Protection Fund. The North will never agree to tax themselves to the extent suggested. Indeed it is in their interests to keep unemployment and social divisions high in the South, as it is the interests of our elite too. Such a programme should be financed through taxing the rich agriculturists, denying subsidies to industries and levying an environment tax on city-dwellers. I do not want here to go into the details of the eco-regeneration programme.

I do not know how you can incorporate my comments in your draft. If you succeed in bargaining on the position taken in the draft, nothing like it. All good luck to you!

25 years after Rio

It is 25 years after the first multi-nation conference called the Rio Earth Summit, specifically focused on climate change, was convened in Rio de Janeiro in 1992 and saw representation from 172 nations. 108 Heads of State attended this summit. It is worth looking at the current status vis-à-vis outcome of the Rio conference and in the context of Prof. Gole's input to the India delegation which represented our country then. This note tries to take stock of where we stand 25 years hence and is there anything that is done in the

direction of what Prof. Gole suggested in his letter to Sunita Narayan and Anil Agarwal of CSE.

This commentary refers to the position that was stated by Professor Gole in his communication to incorporate views on India's position at the Rio Earth Summit 1992. The communication titled 'The Rio Conference – Some Bare Truth' is reproduced below this note for reference.

In the last 25 years, against the base commitments by many countries, our fossil fuel use has certainly not plateaued or decreased. It has only shifted more and more to the South (i.e. more developing and populous nations) making China at #1 and India at #4 among the top five CO_2 emitters in the world. Aggregate energy use in the world has only increased. Even while India's per capita emission is substantially below the world average, the aggregate emission is now at #4. This has been so for two reasons – The North (i.e. developed countries including the West and Japan) has found a way to enjoy the benefits of goods and services to their liking, but by externalizing the cost by outsourcing and importing the goods of necessity and luxury. The countries supplying these goods are bearing the brunt of pollution and also taking the blame of polluting, even while the North is enjoying the fruits of these products and services and claiming that they are using similar level of energy as before or have dipped marginally in the energy use within their boundaries.

One of the key phrases used by Anil Agarwal and Sunita Narayan in their discourse then was 'Global Environmental Democracy'. If we interpret this literally, a global citizen must be able to decide what she or he wants from the environment and must have a corresponding choice. Unfortunately, most of the citizens of the world, predominantly from the South, still do not have that option. One section of the populations across the world, irrespective of the country borders, consume as much as they want to, emit far more carbon in the atmosphere than they should, and the consequences are being borne by those who do not necessarily belong to this section and do not have a wherewithal to counter the downsides for this negative environmental impact. This is not just so with CO_2 emission but true of all the commons. Garret Hardin's 'Tragedy of the Commons' is showing its most serious facet in terms of climate change today. Bottom line – we are as far away from achieving Global Environmental Democracy and are at the same place as we were in 1992, if not in a worse position. Only difference that we see has happened is that people do talk about this as an important subject and give it only a lip service in most cases. Even then I believe this is one positive step.

If we look locally and our position at large, there is still the same divide between the haves and have nots as 25 years ago. If at all, it has increased. Income share of the top 1% has grown by around 8% since 1993. Clearly, this is at the expense of the remaining population. It may be argued that percentage of people living below poverty line has decreased substantially in absolute terms and the economic dividends are making some headway in relieving the short-term poverty situation in the country. But the data also says that this has not resulted in equivalent reduction in malnourished and hungry children. There is only a marginal improvement (46% to 40%) compared to the more dramatic reduction in absolute poverty from more than 50% to around 21%. It must however be noted, that is at the expense of continued damage to the commons which is bound to lead to serious questions on sustainability in view of energy and other resources. Having said that, has the income of the poor grown at the pace of income of the already rich? A sad state of affairs one must admit. The divide between the city and the countryside continues, even while some welcome moves to make villages better are coming forth. Hopefully villages do not become another incarnation of cities and become unsustainable and energy guzzling beasts. Moreover, increased dependence of products of fossil fuels in terms of agrochemicals and fertilizers is leading to substantial loss in soil quality and water quality.

Prof. Gole had suggested strengthening village institutions then. There have been some positives in terms of putting decision making at the village level. The concept of Panchayat Raj has been a good political experiment in this direction, however we may not be able to say that of most other village institutions today. There is an ongoing need to strengthen the healthcare infrastructure and capability in rural areas. Should wisdom prevail, decision making at the Panchayat level could make changes in the desired direction. Efforts by village communities to own and conserve forests and other natural resources around them are more of an exception than a rule, though the constitution now gives them this ability.

Prof. Gole's prophecy of continued use of brute force for resources (read 'Oil') after 1989 Iraq world war has also come true. We have had the 2001 Iraq war as an unfortunate testimony.

The current perspective of most policy-makers and business leaders is very much anthropocentric and there is no realization that unless we as humans take

care of all the Bio-Physical capital and assets at large, we have no real future.

There has been some movement in the direction of vocational education in schools at least at an education level. Hopefully, this will be translated into creation of good quality jobs in the countryside. The program of mass scale ecological regeneration to create jobs and conserve natural resources, proposed by Agarwal and Narayan and also by Prof. Gole, has still not taken off. On the contrary, industries are being further subsidized and protection of our nature continues to be a serious question mark.

Policies do not seem to be oriented towards better equity and sustainability. The direction still is GDP growth, which translates into accelerated pace of natural resource use under the assumption that this will bring us out of poverty. This effectively means we are moving towards an unsustainable world more quickly.

One of the suggestions that came from Prof. Gole was denying the market access to the North by the developing world as a negotiating tool for resource equity. The reality today is probably exactly the opposite; most markets of the South are wide open for business for the North, courtesy WTO. Interestingly, the North is facing a bit of heat more due to labor mobility and they are now turning protectionist, after having fully reaped the fruits of global high-value trade. Would that mean that they will be all fine if South denies them to get in their markets? I doubt if that would be so. The North has become more and more dependent on the South not just as a market but also as a factory of the world. The world has become far too interconnected for any easy resolution of who is whose market.

To summarize, Professor Gole's inputs are at least as valid as they were 25 years ago, if not even more valid today. He had commented that a proposed 'Planet Protection Fund', where using more technology to solve the problems of 'pollution' in the developing word is not a sound idea as historically, more technology has meant even more pollution at a planet level. A similar idea has been proposed again at COP21 in Paris (2015) and it was accepted that a fund be created by the developed nations. However due to political reasons at the international level, such a fund is not yet functioning in any serious way.

The increased change of pace of doing business, extensive dependence on IT and other complex technologies, higher per capita calorie intake, and hunger for mobility of the global population, are further accelerating use of natural resources and change in land use. This is creating further stress on already stressed planetary boundaries. We are on the way to 6^{th} Mass extinction, the world is warming at a rapid pace and looks like we will cross the 2^0C critical limit. Countries seem to be saying that they will follow protectionist policies – which might be a ray of hope in fact. Globalization and its untoward impacts on social and ecological health of countries might just get arrested by these overtures by countries like the US and the UK. The US however might flout all the restraint required on fossil fuel use, which has always been a contentious issue. This will raise further questions on a sustainable future.

The ensuing scenario will be topsy-turvy at best. We must continue with our efforts to push for ecological restoration as means to restoring natural wealth and at the same time create a large number of jobs. Supplementing these with vocational inputs and village improvement programs for sustainable future will remain important for us to tread a path of improved well-being for the masses.

UNDP has been working on finding ways to make the world a better and more equitable place and has come up with Millennium Development Goals (MDGs) in 2000 and Sustainable Development Goals (SDGs) in 2015. While these initiative cover some of the areas, both these still subscribe to the economic growth paradigm in conventional terms, which makes the possibility of sustained success a huge challenge. India, has performed modestly on the MDG front. A detailed analysis is available at http://www.in.undp.org/content/india/en/home/post-2015/mdgoverview.html.

Prof. Gole would have questioned the technology and growth paradigm that is professed while talking about implementation of MDGs and SDGs. He would have hoped that a more holistic and bio-environmental approach would make far more sense than keeping the current anthropocentric model with excessive focus on technology.

His visionary thinking, this reprint being an example, continues to guide us at Ecological Society.

The theme of this issue of the Journal is man-wildlife interface. Man, has always been fascinated by the wildlife around him. Here are some snapshots over the centuries...

Varahamihir (505-587 CE) was a pioneering astronomer, mathematician and scientist from Ujjain, India. In his encyclopaedic work *Brihat-Samhita*, he documents many natural phenomena, including plants and animals. In one such observation, he mentions,

हयनरभुजगोष्ट्रद्वीपिसिंहर्क्षगोधा | वृकनकुलकुरंगश्वाजगोव्याघ्रहंसाः ॥

पृषतमृगशृगालश्वाविदाख्यान्यपुष्टा | द्युनिशमपि बिडालः सारसः सूकरश्च ॥

(The horse, man, snake, camel, lion, bear, monitor lizard, wolf, mongoose, antelope, dog, goat, cow, tiger, swan, spotted deer, jackal, porcupine, cuckoo, cat, sarus crane, and the pig, are all diurnal as well as nocturnal animals)

Ida Pfeiffer (1797 – 1858) was one of the earliest woman explorers who travelled around the world. She was a member of geographical societies of both Berlin and Paris. During 1846-48 she travelled to South America, Tahiti, China, India, the Middle East, and Greece.

...One of the most interesting excursions of my whole journey was to the ruins of the town of Fattipoor-Sikri.....On our way, we passed at times over extended heaths, on one of which we saw a small herd of antelopes. The antelope is a kind of deer, but smaller in size. It is extremely delicate and prettily formed, and is distinguished by narrow dark-brown stripes along the back. The herd crossed the road before us without much timidity, passing over ditches and bushes, and leaping more than twenty feet at a time, with such graceful movements that they seemed as if dancing through the air. I was not less delighted by the sight of two wild peacocks. It afforded me peculiar pleasure to see these animals in a state of freedom, which we Europeans are accustomed to keep as rarities like exotic plants.....These birds are considered by the Indians almost as sacred as the cow. They appear to fully understand this kindness, for they are seen, like house-birds, walking about in the villages, or quietly resting upon the roofs.

- *Eine Frau fährt um die Welt (3 vols., Vienna, 1850; English translation: A Woman's Journey round the World, London, 1850).*

Durga Bhagwat (1910-2002) was an anthropologist, researcher, socialist, and acclaimed Marathi writer. Among her many interesting works is अस्वल (The Bear), a well-researched Marathi book dedicated to everything about the Indian species of bear.

...भारतीय अस्वला हा काय लेखनाचा किंवा संशोधनाचा विषय आहे? प्राणीशास्त्रज्ञाने वाटले तर त्याच्यावर लिहावे. पण मानवशास्त्रज्ञाने त्याच्यावर लिहिण्यासारखे काय आहे? असेच अनेकांना वाटते. कदाचित मी निसर्गवेडी नसते व मानवशास्त्राची अभ्यासक नसते, तर मलाही असेच वाटले असते.....परंतु योगायोगाने १९३६ च्या सुमारास एक दिवस मी एशियाटिक सोसायटीच्या ग्रंथालयात अजंठ्याच्या चित्रांचे ग्रिफिथ्स यांनी तयार केलेले पुस्तक पाहिले. त्यात अस्वलाने लहिवाळपणे मांडीवर घेतलेला माणूस मी पाहिला आणि माझ्यात अस्वल व माणूस यांच्या संबधांच्या बाबतीत कुतूहल निर्माण झाले. मी भारतीय अस्वलाबद्दल माहिती गोळा करण्यास सुरुवात केली...

- *अस्वल (वरदा बुक्स, पुणे, १९८२)*

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