Environmental Monitoring Report

Annual Report
March 2017

BHU: Second Green Power Development Project (118 MW Nikacchu Hydropower Project)

Prepared by the Tangsibji Hydro Energy Limited for the Asian Development Bank.

Contents

Annexures

Abbreviation

ADB	Asian Development Bank
AP	Affected Person
BP	Batching Plant
BHUCORE	Bhutan Consultancy on Research
CCF	Contractor Construction Facility
CNR	College of Natural Resource
CoEVATA	Center of Excellence in Vibration and Thermographic Analysis
CPS	Community Primary School
dB	Decible
DGPC	Druk Green Power Corporation
DHMS	Departement of Hydro Met Services
DHPS	Department of Hydropower and Power Syetems
DLLC	Dzongkhag Land Lease Committee
DoFPS	Department of Forest and Park Services
DoL	Department of Livestock
DPR	Detailed Project Report

EMP	Environment Management Plan
ESIA	Environment and Social Impact Assessment
ESP	Elementary Service Personnel
Ft	Feet
GNHC	Gross National Happiness Commission
GRFL	Government Reserve Forest Land
GSB	Granular Sub-Base
HEP	Hydro Electric Project
HRT	Head Race Tunnel
JSWNP	Jigme Singye Wangchuk National Park
KM	Kilo Meter
kV	Kilo volt
M	Meter
MD	Muck Disposal
MoEA	Ministry of Economic Affairs
MoLHR	Ministry of Labour and Human Resource
MoU	Memorandum of Understanding
MU	Million Unit
NBC	National Biodiversity Center
NCRLF	National Center for Riverine and Lake Fisheries
NEC	National Environment Commission
NGO	Non-Governmental Organization
NLC	National Land Commission
PAP	Project Affected People
PFS	Pre-Feasibility Study
PPE	Personal Protective Equipment
PSMP	Power System Master Plan
PwC	Price water Cooper
PoE	Panel of Expert
RP	Resettlement Plan
RPM	Respirable Particulate Matter
Sqft	Square feet
TCBEM	Technical Committee for Biodiversity and Environment Management
THyE	Tangsibji Hydro Energy Limited
TSPM	Total Suspended Particulate Matter
UWICER	Ugyen Wangchuk Institute for Conservation of Environment and Research
WMD	Watershed Management Division
WPMA	Waste Protection and Management Act

Executive Summary

The Royal Government of Bhutan has approved construction of 118 MW Nikachhu Hydropower Project in April 2014 after which preconstruction works began in December 2014 followed by award of main contract package in April 2015 to M/s Hindustan Construction Company. All sites were handed over to the contractor in May 2015 in including access roads and construction facilities.

The first blast was commenced on 2nd August, 2016 for Diversion Tunnel at Dam followed by blast at Adit-III and Adit-II. The project has now completed excavation of Diversion Tunnel. Except for Adit-IV and Adit-V works at all other fronts have began.

The Environment Management Plan and Resettlement Plan implementation are in full swing and monitoring of implementation by contractor is done as well. Apart from the activities highlighted in EMP, THyE has also initiated other conservation activities to mitigate potential impact the project might have on the natural habitat.

Further, for well being of Project Affected People at the community various community development programs listed in Resettlement Plan, in consultation with PAP, Geog Administration and Dzongkhag Administration are implemented. After the execution of project other development proposal from Geog Administration were also considered and executed to improve the livelihood of the community.

The main monitoring at site is particularly for waste, health, safety, effluent, air quality in Tunnels and ambient. Currently the contractor has employed about 324 workers included technical people all of whom are provided with proper shelter and services. Due to consistent coordination between THyE and contractor no adverse environmental issues has raised till date. The contractor has not yet fully established with equipment and workers, however, THyE expects that the contractor shall gradually improve.

1.0. Introduction

1.1. Brief Project Description

Tangsibji Hydro Energy Ltd (THyE), a fully owned subsidiary of Druk Green Power Corporation Limited was incorporated, on April 25, 2014, as a Special Purpose Vehicle to develop 118 MW Nikachhu Hydropower Project. The 118 MW Nikachhu Hydro Power Project was identified in the updated Power System Master Plan (PSMP) of Bhutan (2004). The Pre-Feasibility Study (PFS) that was completed on 31 December, 2011 followed by Feasibility Study in September 2012. The Detailed Project Report was completed in September 2013.

Bhutan Consultants & Research (BHUCORE) carried out Environmental and Social Impact Assessment (ESIA) of the Nikachhu project on June 1, 2012, and revisions to the ESIA report have been made by PWC India consultants under the technical assistance of Asian Development Bank (ADB). The report constitutes three parts comprising Environment and Social Impact Assessment (ESIA), Environment Management Plan (EMP) and Resettlement Plan (RP)

With an estimated energy generation of 491.52 MU, 85 % shall be exported which will not only enable revenue generation for the nation but reduce Green House Gas emission in the neighbouring country by replacement of fuel by clean and renewable energy, hydropower. Further, the outflow from Nikachhu Project into Mangdechhu reservoir provides additional energy generation of 323.77 MU to Mangdechhu Hydro Electric Project.

Nikachhu Hydropower Project is located in Trongsa and stretches over 25 km from Dam, at Lorim, to Power House, at Norbuodi with 12.14 km Head race Tunnel (HRT) having five intermediated adits. With the construction of 38 m high dam, 12.28 acres of land will be impounded by 810 m water back-flow.

1.2. Project Progress Status and Implementation Schedule

Prior to ABD loan disbursement, pre-construction works such as Acess road to dam site and access roads to Adits was carried out from December 2014. These included infrastructure facilities such as access road of 18.388 km, about 8 km construction power line, water supply arrangement, residential, labour camps and offices were constructed.

Table 1.1 Project schedule and activities

No.	Activity	Amount	Awarded	Completed	Remarks
1	Access Road to Dam site Road length- 2.10 km	Contractor: Construction Development Corporation Limited, Thimphu Contract Amount: BTN 34,791,955.00	Contract Agreement signed on 15th October, 2014 Formation cutting started on 28th November, 2014	Road Handed over on 12th November, 2015 Camp demobilized on 1st December, 2015	Contract completion cost BTN 48,090,124.50
2	Construction of 30 m span 24R Bailey Bridge:	Contractor: Construction Development Corporation Limited, Thimphu Contract Amount: BTN 14,812,670.43	Contract Agreement signed on 15th October, 2014	Handed over on 12th November, 2015	

	Access road to Adit-I Road length-2.278 km	Contractor: M/s Gayjur Construction Private Limited, Mongar Contract Amount: BTN 18,760,650.00	Letter of award issued on 19th October, 2014 Contract Agreement signed on 1st November, 2014	Taken over 15th December, 2015.	Contract completion cost BTN 31,779,469.50
	Access road to Adit-II and Adit-III Road length-1.973 km+ 1.943 km	Contractor: M/s Lamnekha Construction Private Limited, Thimphu Contract Amount: BTN 50,626,000.00	Letter of award issued on 19th October, 2014 Contract Agreement signed on 3rd November, 2014	Road taken over on 2nd November, 2015	Contract completion cost BTN 93,554,613.52
	Access road to Adit-IV, V, and Surge Shaft Road length-0.577 km+0.417 km+ 1.5 km	Contractor: M/s Gyalcon Infrastructure Private Limited, Thimphu Contract Amount: BTN 22,678,100.00	Letter of award issued on 19th October, 2014 Contract Agreement signed on 1st November, 2014	Road taken over on 2nd November, 2015	Contract completion cost BTN 41,749,024.00
	Access road to Power House Road length- 7.6 km	Contractor: M/s Tshering Construction Private Limited, Bumthang Contract Amount: BTN 60,158,750.00	Contract Agreement signed on 1st November, 2014	Completed but not taken over due to some additional works	Contract completion cost BTN 108,005,053.40

	Water supply arrangement to Dam and Adit I	Contractor: M/s TGD Construction, Trongsa BTN 2,838,862.50	Letter of Award issued on 27th December, 2014. Contract Signed on 12th January, 2015	Completed on02 October, 2015	Contract completion cost BTN 3,874,114.95
	Water supply arrangement to Adit II,III &IV	Contractor: M/s L.S. Construction, Trongsa Contract Amount: BTN 1,820,936.10	Letter of Award issued on 27th December, 2014. Contract Signed on 12th January, 2015	Completed on 10 December, 2015	Contract completion cost BTN 2,380,141.4
	Water supply arrangement to Adit V, Surge Shaft & Power House	Contractor: M/s Karma Tshering Construction, Bumthang Contract Amount: BTN 3,356,028.78	Letter of Award issued on 27th December, 2014. Contract Signed on 12th January, 2015	Completed on 26 November, 2015	Contract completion cost BTN 3,433,861.29
	Contractor facility at Dam, Adit-I &Adit-II	Contractor: M/s Gayjur Construction Private Limited, Lingmithang Contract Amount: BTN 28,477,299.24	Contract Agreement signed on 5th May, 2015 Letter of award issued on xxx ,	Completed on 07 May, 2016	Contract completion cost BTN 49,750,852.10

	Contractor facility at Adit-III, Adit-V, Surge Shaft & Power House	Contractor: M/s Z&K Construction Private Limited, Thimphu on 7th April, 2015 Contract Amount: BTN 31,843,544.50	Contract Agreement signed on 22nd April, 2015 Letter of commencement of work issued on 1st July, 2015	Completed on 18 May, 2016	Contract completion cost BTN 58,314,353.97
	Client facility at Dam Site	Contractor: M/s Lamnekha Construction Private Limited, Thimphu Contract Amount: BTN 18,558,838.10 Contract Duration: 4.50 months	Letter of Award: 5th June, 2015 Contract Agreement signed on 20th June, 2015	Completed 25 May, 2016	Contract completion cost BTN 41,038,906.68
	Client facility at Power House	Contractor: M/s Gyalcon Infrastructure Private Limited, Thimphu Contract Amount: BTN 18,247,704.75 Contract Duration: 4.50 months	Letter of Award: 18th June, 2015 Contract Agreement signed on 3rd July, 2015	Completed on 20 May, 2016	Contract completion cost BTN 21,778,260.13
	Construction power arrangement	Contractor: BPC	MoU signed with BPC on 15th August,	Completed in June, 2015	Completion date: was May, 2015

		Contract duration: 9 months	2014.		
	Main package	M/s Hindustan Construction Company limited (HCC)	Contract Agreement signed on 20th March, 2016	Contractor mobilized, Diversion Tunnel excavation complete, Adit I-9m, Adit II-203 m, Adit III- 237 m, BVC-67m, IPS-7m	

1.3. Compliance to National Regulations

1.3.1. Terms and Conditions of Environmental Clearance

The table below shows the compliance of project execution in line with terms and conditions of Environment Clearance issued by National Environment Commission of Bhutan vide letter no. NECS/ESD/DGPCL/1837/2014/8446 dated 1st July, 2014 and renewed vide no. NECS/CMD/THyE/1837/336/2016/1707 dated 12th August, 2016.

Table 2.1 Compliance with Environment Clearance issued by National Environment Commission

Sl.no	Reference to Environmental Clearance	Relevant Condition	Compliance
1	Clause 9	The holder shall ensure that the implementation of the proposed project is strictly confined within the allocated area.	Complied.
2	Clause 15	The holder shall ensure that local residents, households, communities, public, private parties and religious, cultural, historical and ecologically important site are not adversely affected by the construction of proposed project.	Complied, except for the household below the access road of Adit-III, which was damaged by a falling boulder. However, a new house has been constructed with better facilities and handed over to the owner.

3	Clause 18	The holder shall ensure that the implementation of the proposed project, except the Dam, does not lead to blockage, storage or diversion of river, stream, irrigation channel, waterfall and underground water source.	Complied.
4	Clause 19	The holder shall ensure that a buffer of at-least 100 ft is maintained between the project activities and water streams.	Maintaining buffer from streams was not practical where the road alignment has to cut the water body. However, mitigation measures, for elimination of impact on water, such as causeways, and hume pipes were constructed.
5	Clause 21	The holder shall ensure Biodiversity Management Plan and Compensatory Afforestation Program are implemented in co ordination with the DoFPS to minimize biodiversity impacts.	Complied. The institutional arrangements are in place and activities being initiated.
6	Clause 22	The holder shall ensure that the construction works at Adit-II are not carried out from 10 pm to 6 am.	Complied.
7	Clause 24	The holder shall ensure that felling of trees if required are done only upon obtaining approval from DoFPS and as per the conditions of the approval.	Complied.
8	Clause 28	The holder shall ensure that Environment Friendly Road Construction techniques are adopted for construction of access roads.	Complied. The road construction adopted was cut-fill method and Bio-engineering measures were taken comprising seed broadcasting, stem cutting, protection works and plantation.
9	Clause 29	The holder shall ensure that the bio-engineering practices are adopted on all road side slopes.	Complied. Grass seed broadcasting were carried out at all access road

			slopes.
10	Clause 30	The holder shall ensure construction of side drains, cross drains, causeways, and other supporting structures are required to prevent soil erosion, improve usability and sustainability of road.	Complied.
11	Clause 36	The holder shall ensure that no raw materials of any kind, machineries, plants and equipments and excavated materials are staked along the highway.	Not Complied due to space constraint at the access road side. The GSB materials were stacked near the Highway at ADIT-I however now has been utilized and cleared.
12	Clause 37	The holder shall ensure safe and smooth flow of traffic along the highway.	Complied. However, the flow is hindered by on-going East-West National Highway widening activity.
13	Clause 40	The holder shall ensure dusts are suppressed.	Complied.
14	Clause 46	The holder shall ensure that dump sites are stabilized with appropriate protection measures	Complied.
15	Clause 52	The holder shall ensure that waste generated from the labour camps and work sites are managed as required under WPMA of Bhutan.	Complied.
16	Clause 59	The holder shall ensure that safety gadgets are provided to all workers and any person entering the worksite.	Complied.
17	Clause 66	Ensure that signboard are erected at the starting point of the project area	Complied

1.4. Compliance to Environmental Covenants from the ADB Loan Agreement

1.4.1. Schedule 5 Environment

Table 3.1 Compliance to Environmental Covenants

Sl.No	Relevant Condition	Reference	Compliance status
1	The Beneficiary shall ensure, or cause DGPC and THyE to ensure, that the preparation, design,	Financing Agreement,	Complied.

	construction, implementation, operation of the Project and all Project facilities comply with (a) all applicable laws and regulations of the Beneficiary relating to environment, health, and safety; (b) the Environmental Safeguards; (c) the EIAs; and (d) all measures and requirements set forth in each EIA and EMP, and any corrective or preventative actions set forth in a Safeguards Monitoring Report.	Schedule 5, Paragraph 3	
2	The Beneficiary shall ensure, and cause DGPC and THyE to ensure, that (a) there are no measurable adverse impacts on critical habitat that could impair its ability to function; (b) there is no reduction in the population of any recognized endangered or critically endangered species; and (c) any lesser impacts are mitigated. Without limiting the generality of the foregoing, the Beneficiary shall cause DGPC and THyE to establish a biodiversity management committee acceptable to ADB that (a) shall be responsible for implementation monitoring and evaluation of the biodiversity conservation and biodiversity management plan as outlined in the relevant EMP and (b) shall ensure that the Project facilities are constructed and operated in a manner consistent with the JSW National Park Management Plan	Financing Agreement, Schedule 5, Paragraph 4	Complied.
3	The Beneficiary shall cause DGPC and THyE to (a) assess on a continuous basis, in accordance with the relevant EMP, the minimum environmental water flow requirements during the operation of the Project facilities; and (b) ensure a minimum water flow, at a level acceptable to ADB, so as to minimize downstream impacts and make sure there is no net loss of downstream aquatic biodiversity arising from the operation of hydropower facilities in the Mangdechu river basin, including from the Project facilities and the Mangdechu Hydroelectric project. The Beneficiary shall cause DGPC to establish a funding mechanism or internal resources to ensure integrated water resources management for the Mangdechu river basin, including compliance with the minimum environmental water flow requirements as set out in the preceding sentence	Financing Agreement, Schedule 5, Paragraph 5	Not relevant at this stage of project phase.
4	The Beneficiary shall ensure, or cause DGPC and THyE to ensure, that all land and all rights-of-way required for the Project, and all Project facilities are made available to the Works contractor in accordance with the schedule agreed under the related Works contract and all land acquisition and resettlement activities are implemented in compliance with (a) all applicable laws and regulations of the Beneficiary relating to land acquisition and involuntary	Financing Agreement, Schedule 5, Paragraph 6	Complied.

	resettlement; (b) the Involuntary Resettlement Safeguards; and (c) all measures and requirements set forth in the RP, and any corrective or preventative actions set forth in a Safeguards Monitoring Report.		
5	Without limiting the application of the Involuntary Resettlement Safeguards, and the RP, the Beneficiary shall ensure or cause DGPC and THyE to ensure that no physical or economic displacement takes place in connection with the Project until (a) compensation and other entitlements have been provided to affected people in accordance with the RP; and (b) a comprehensive income and livelihood restoration program has been established in accordance with the RP	Financing Agreement, Schedule 5, Paragraph 7	Complied.
6	Submit quarterly Environmental Safeguard Monitoring Reports and semi-annual Involuntary Resettlement Safeguards Monitoring Reports to ADB during construction of the Project facilities and annual Environmental Safeguard Monitoring Reports during operation of the Project facilities, and disclose relevant information from such reports to affected persons promptly upon submission;	Financing Agreement, Schedule 5, Paragraph 11, bullet 'a'	Complied.
7	If any unanticipated environmental and/or social risks and impacts arise during construction, implementation or operation of the Project that were not considered in the relevant EIA, EMP or the RP, promptly inform ADB of the occurrence of such risks or impacts, with detailed description of the event and proposed corrective action plan;	Financing Agreement, Schedule 5, Paragraph 11, bullet 'b'	Complied. No such risks arose except the house damaged at Adit-III which was rebuilt and handed over.
8	No later than 31st March, 2015 engage a panel of experts to monitor and report upon Project implementation, and facilitate the carrying out of any monitoring activities by such panel; and	Financing Agreement, Schedule 5, Paragraph 11, bullet 'c'	Complied.
9	Report any actual or potential breach of compliance with the measures and requirements set forth in the relevant EIA, EMP or the RP promptly after becoming aware of the breach.	Financing Agreement, Schedule 5, Paragraph 11, bullet 'd'	Complied. All requirements are being fulfilled and some being initiated without any breach.

1.5. Environmental Safeguards

1.5.1. Institutional set up

The Environment Management Unit of THyE was established 0n 1stst September, 2014 with the mandate to ensure implementation of Environment Management Plan and to ensure compliance with National Laws and Regulations, and conditions laid out in the Environmental Clearance issued by NEC, as well as those of the ADB. The Unit resolves all social, safety and environmental issues and facilitate contactors in pursuing required clearances and approvals. The Environmental unit is staffed with two employees the Head of Unit and an Elementary Service Personnel (ESP). The looks into implementation of Resettlement Plan of the project including processing affected land compensation, monitor implementation of EMP by the contractor, implement EMP and initiate Biodiversity Conservation activities in collaboration with various agencies including NGO.

The Environment Unit reports to Chief Administrative Officer of Human Resource and Administrative Division who further reports to Managing Director.

1.5.2. Implementation of the Environmental Management Plan

1.5.2.1. Land Acquisition (Temporary and Permanent)

In the Environment and Social Impact Assessment (ESIA) and the EMP during the Detailed Project Assessment, it was estimated that the total project land requirement was about 0.27% of the land area of Tangsibji Geog. The temporary land acquisition is equivalent to 262.50 acres, including the 59.3 acres land for the Transmission Line of Construction Power, with permanent land acquisition being equivalent to 45.66 acres. However, as per the requirement of National Land Commission (NLC) 195.262 acres of Government Reserve Forest Land (GRFL) was taken on lease of which 18.66 acres are for permanent structures and 176.602 acres for temporary facilities. The land for permanent structures is leased for 30 years and temporary structures for 5 years.

For the access road construction, it was estimated that 3.577 acres of private land belonging to 11 households and One Community Primary School would be affected. Therefore, compensation was paid of to all the identified affected households including the land development cost. After the completion of access road construction affected area were resurveyed to find out the actual impact on the private land by the access road. Since then it was found that the affected land has increased from the initial estimated by 3.882 acres. In addition to Eight (8) affected households already indentified in DPR three (3) new households were found to be affected during the actual construction work. The details of initial and additional land and household affected are given in the table below:

Table 4.1 Additional affected land

Sl. No.	Name	Plot No.	Thram Area	Affected Area	Acquired area (Ac)	Additional Land affected
1	Sumchokmo	TAN-3253	0.406	0.406	0.000	0.404
2	Dorji	TAN-1843	2.150	0.585	0.480	0.105
3	UgyenZangmo	TAN-1842	0.880	0.213	0.107	0.106
4	SonamWangchen	TAN-1889	0.699	0.699	0.210	0.489
	SonamWangchen	TAN-1873	1.047	0.183	0.132	0.051
5	KunzangWangmo	TAN-1909	0.372	0.372	0.165	0.207
6	DorjiDema	TAN-1863	0.460	0.433	0.126	0.307
7	TshewangLhamo	TAN-1865	0.888	0.469	0.094	0.375
	TshewangLhamo	TAN-1867	0.700	0.700	0.375	0.327
8	Phub Zangmo	TAN-1855	0.563	0.563	0.241	0.322
9	TshewangGyeltshen	TAN-1875	0.577	0.116	0.000	0.116
10	RinzinWangmo	TAN-1876	0.372	0.372	0.000	0.372
11	TshangTshangDorji	TAN-1878	0.526	0.526	0.197	0.329
	TshangTshangDorji	TAN-1879	0.527	0.527	0.155	0.372
TOTAL				**6.164**	**2.282**	**3.882**

The affected area for the following four (04) households and the Community Primary School remained unchanged from DPR:

Table 5.1 Initial identified housholds without additional affected

Sl.no.	Thram No	Project Component	Name	Land Type	Thram Area	Acquired
1	527	Adit-III	NamgayChholing CPS	Institutional Land	2.819	0.423
2	270	Power House	DorjiZangmo	Kamzhing	1.200	0.183
3	262		UgyenTshomo	Kamzhing	1.120	0.280
4	240		SonamPelmo	Kamzhing	0.765	0.142
5	258		DorjiDema	Kamzhing	0.872	0.267
Total Area (Acres)						**1.295**

Compensation in Bhutan is guided by the principle that no household should be worse off compared to their existing living conditions. Land compensation is therefore guided by the "Land Compensation Rates (2009)" and the Land Act of Bhutan (2007). The Land Act 2007, states that acquisition shall entail fair compensation. The compensation can be in cash or land or a combination of both, the land owner shall have the discretion to opt for one or the other. The total private land acquired for the project is 7.459 acres.

1.5.2.2. Cadastral surveys

Two phases of Cadastral surveys were conducted in coordination with Dzongkhag Administration in October, 2015 to determine the actual impact of access road construction on private land as well as GRFL. The report was then submitted to the project for compensation.

Figure 1.1 Cadastral surveys for land compensation of main project component

Cadastral survey for private land along the 18.6 km, 132 kV transmission lines that will affect 0.6 acres of private land at Drakten and Langthil was also carried out from 25-28 January, 2016. As per the report private land of only five (5) households are affected by tower footings instead of six (6) identified in DPR.

Figure 2.1 Cadastral survey for PAPs of Transmission Line

1.5.2.3. Consultations with affected persons

Consultations with the all the affected households were carried out in presence of Geog administration 11th -12th January, 2016. Further, the most recent consultation was done by the

Social Development Expert from 02nd-09th October, 2016. During the meeting people were proposed to provide their opinion on the project and the impact it has on their community. No negative opinion was raised except at Tsangkha where concerns were raised for land compensation.

During the Public consultation for transmission line held in August 2014, it was decided that although the affected area is less than 0.10 acre, at least 0.10 acre shall be acquired to allow PAPs eligible for land-for-land compensation. As per the Land Act of Bhutan, only cash compensation is entitled for PAPs whose land affected is less than 0.10 acre. The compensation process is being kept on halt due to an ongoing survey carried out by Royal Government of Bhutan (RGoB) to provide Kidu (grant) lands which are measured from GRFL. THyE anticipates more households to be affected so the Project has decided to only carry out the compensation process once the government issues land ownership for Kidu (free land) land.

Figure 3.1 consultation with Project Affected People

1.5.2.4. Land compensated

Although only 3.577 acres of private land belonging to 11 households and One Community Primary School were identified during the project planning stage, an additional 3.882 acres of eleven (11) additional households were affected during the actual road construction works. Compensation to all the additional affected households was also paid off on 07th October, 2016. Along with Land substitution land development cost was provided as per the Resettlement Plan (Nu.75,000/acre of dryland) to all the affected households as listed below in the table:

1. Land substitution

Table 6.1 Land subsitution list

Sl. No.	Thram No.	Land Owner	Substitute Land Name	Area (Ac)	Location
1	269	Tshang Tshang Dorji	Phubgyemsa	0.701	Tshangkha
2	254	Rinzin Wangmo	Tenka	0.372	Tshangkha

3	58	Ugyen Zangmo	Kechula zhunglamtak	0.106	Tashiling
4	255	Sonam Wangchen	Gochegma	0.540	Tshangkha
5	268	Tshewang Gyeltshen	Nimseelay	0.116	Tshangkha
6	510	Sumchokmo	Kipheynang	0.294	Tashiling
			Buzilamtak	0.110	Chendebji
7	272	Tshewang Lhamo	Gebeeledenang	0.210	Tashiling
			Banglachubar	0.250	Banglapokto
			Kubeezur	0.242	Sakarchewa
8	257	Phub Zangmo	Seamjoeleng	0.322	Tshangkha
9	56	Dorji	Gokham	0.105	Dangla
10	181	Kunzang Wangmo	Taktshang	0.107	Taktshang
			Kawachaksazhunglamtak	0.100	Tashiling
11	258	Dorji Dema	Leychhu	0.307	
TOTAL				**3.882**	

2. Land development cost

Table 7.1 Land development cost detail

Sl. No.	Thram No.	Name	Land Name	Thram Area	Additional Land compensated (Ac)	Land development cost (Nu.)
1	510	Sumchokmo	Nyala	0.406	0.404	30,300.00
2	56	Dorji	Lorim	2.150	0.105	7,875.00
3	58	Ugyen Zangmo	Lorim	0.880	0.106	7,950.00
4	255	Sonam Wangchen	Dorteng	0.699	0.489	36,675.00
	255	Sonam Wangchen		1.047	0.051	3,825.00
5	181	Kunzang Wangmo	Draktsawa	0.372	0.207	15,525.00
6	258	Dorji Dema	Dragitsawa	0.460	0.307	23,025.00
7	272	Tshewang Lhamo	Samrang Gongwog	0.888	0.375	28,125.00
	272	Tshewang Lhamo		0.700	0.327	24,525.00
8	257	Phub Zangmo	Leaychu	0.563	0.322	24,150.00

9	268	Tshewang Gyeltshen	Leaychu	0.577	0.116	8,700.00
10	254	Rinzin Wangmo	Leaychu	0.372	0.372	27,900.00
11	269	TshangTshang Dorji	Tangsey dragchun	0.526	0.329	24,675.00
	269	TshangTshang Dorji	Tangsey dragchun	0.527	0.372	27,900.00

For the 132 kV transmission line a total of 0.6 acres of private land at Drakten and Langthil will be required. The Project has requested Dzongkahg Administration to process for land replacement which will be awarded as deposit work to the Dzongkhag. However, all compensation shall be done after the land ownership certificate for the land granted by RGoB is issued.

1.5.2.5. Forest compensation

During the stringing of 33kV distribution line for construction power arrangement to Adit V, Adit III and interconnection line between Kewathag and Indochholing sub-station, private forest and community forest was affected. To compensate the affected trees, market rate for each tree was paid to the land owner for private forest. For community forest the compensation was paid to the community forest management group. Compensation was paid as per the royalty calculated by the Forest Territorial Division at the rate prescribed by Ministry of Agriculture and Forest.

Table 8.1 Compensation for private and community forests

Sl.no.	Forest owner	Project component	Quantity	Unit	Amount compensated (Nu.)
1	Tshewang Gyeltshen	Distribution line at Adit V	12.00	Nos.	960.00
2	Choki	Distribution line at Adit V	10.00	Nos.	800.00
3	Tshang Tshang Dorji	Distribution line at Surge Shaft	30.00	Nos.	10,720.00
		Distribution line at Adit V	45.00	Nos.	8,400.00
	Tsheringmai Drupchhu Community Forest	Distribution line at Adit III	240.36	cft	65,942.77
5	Endochholing Community Forest	Inter connection line between substations of Endochholing and Kewathnag	1365.67	cft	214,601.66

1.5.2.6. Private Land Leased

For access road to Adit V, since the roadis temporary, it was agreed to lease private land for duration of project completion. Since the land lease rate as prescribed in the Land Lease Rule of Bhutan, 2009 is only Nu.0.1/Sqft/annum, the Projectagreed to the request by the PAPs to increase the lease rate to Nu.1.0/Sqft/annum taking the baseline from Punatsangchhu HEP and Mangdechhu HEP. The lease agreement was then signed on 18 February, 2016.

Construction Facility: Private land belonging to two households was also taken on lease as agreed by the owners for the construction of labour camps at Power House for the main contractors. The lease charges are paid a year up-front therefore till date lease charges for two years were paid to the land owners.

The total private land taken on lease is 1.812 acres of which 1.038 acres are for access road to Adit V and 0.774 acres are for construction of labour camps at Power House.
The details of land leased are given below:

Table 9.1 Private land taken on lease

Project Component	Thram No	Name	Plot No	Thram Area (Ac)	Area to be and/leased (Ac)
Access road-V	246	Palden	TAN-1907	0.480	0.480
	243	Kinley Zangmo	TAN-1906	0.648	0.362
	274	TsheringNorbu	TAN-2872	0.777	0.196
Contractor Construction Facility at Power House	258	DorjiDema	TAN-1880	0.872	0.474
		TshewangNorbu	TAN-1881	0.300	0.300
Total					**1.812**

1.5.2.7. Government Reserve Forest Land

THyE has leased 195.262 acres of GRFL from the National Land Commission (NLC) and Department of Hydropower and Power Systems (DHPS) for which the lease agreement was signed on May 01, 2015. The leased GRFL do not include land acquired for access road construction. During the meeting on 13th August, 2014 with NLC it was agreed that the land for access road shall be leased only after construction is complete. The detail of land leased is as given below:

Table 10.1 Government Reserve Forest Land

Sl. #	Component	Description	Area (Acre)	Temporary (Acre)	Permanent (Acre)

1	Dam	Residential Complex	0.615		0.615
		Non-Residential Complex	2.860	0.480	2.380
		Reservoir Area	12.282		12.282
		Contractor Facility and Establishment	8.144	8.144	
		Batching Plant and Crushing Plant	6.925	6.925	
		Muck Disposal	10.746	10.746	
SUB TOTAL			**41.572**	**26.295**	**15.277**
2	Power House	Residential Complex	1.509		1.509
		Non-Residential Complex	2.634	0.760	1.874
		Contractor Facility and Establishment	16.597	16.597	
		Muck Disposal	17.541	17.541	
SUB TOTAL			**38.281**	**34.898**	**3.383**
3	Surge Shaft	Non-Residential Complex	0.907	0.907	
		Contractor Facility and Establishment	2.994	2.994	
		Muck Disposal	14.309	14.309	
SUB TOTAL			**18.210**	**18.210**	**0.000**
4	HRT and ADITs				
	ADIT - 1	Contractor Facility and Establishment	6.206	6.206	
		Muck Disposal	13.809	13.809	
	ADIT - 2	Contractor Facility and Establishment	2.501	2.501	
		Muck Disposal	18.002	18.002	
	ADIT - 3	Contractor Facility and Establishment	6.502	6.502	
		Muck Disposal	20.530	20.530	
	ADIT - 4	Contractor Facility and Establishment	2.492	2.492	
		Muck Disposal	6.692	6.692	
	ADIT - 5	Contractor Facility and Establishment	2.500	2.500	
		Muck Disposal	12.759	12.759	
5	ADIT to Pressure Shaft	Muck Disposal	5.206	5.206	
		Access Road			
SUB TOTAL			**97.199**	**97.199**	**0.000**
Total Area (Acres)				**176.602**	**18.660**
TOTAL					**195.262**

After the report submitted by Dzongkhag Administration the lease of GRFL for access was applied. The total area to be taken on lease is 8.836 acres.The detail is provided below:

Table 11.1 detail of private land leased

Sl. No.	Access Road to	Area (Ac)	area already in leased area (CCF/MD/BP) (Ac)	Area in Pvt. Land (Ac)	Total area to be leased (Ac)
1	Power House	5.049			NA
2	Surge Shaft	1.900	0.36	0.10	1.440
3	Adit-V	1.270		0.78	0.490
4	Adit-IV	0.802	0.25		0.552
5	Adit-III	2.559	1.24	0.46	0.859
6	Adit-II	3.684	0.70		2.984
7	Adit-I	2.017	0.40	0.13	1.487
8	Dam	2.371	0.65	0.22	1.024
			0.35		
			0.13		
TOTAL		**19.652**	4.08	1.69	**8.836**

From the 19.652 acres of land affected by access road construction, 4.08 acres fall in already leased area. The Land Commission has directed that 5.049 acres affected by the access road to Power House do not have to be leased, so an application has been submitted to the Dzongkhag Land Lease Committee (DLLC) on 25 May, 2016 for the remaining 8.836 acres that are required under lease.

Table 12.1 Schedule for land acquisition or lease

Activities	2015	2016
Cadastral re-survey of affected land and Identification of new land to be given as compensation	05-17 October, 2015	
Finalization of lease agreement with PAPs		Agreement signed on 18 February, 2016.
Lease agreement with National Land Commission for Government Reserve Forest	Agreement for 195.262 acres signed on May 01, 2015	
Application for land to be leased submitted to the Dzongkhag Land Lease Committee (DLLC)		25 May, 2016 for the remaining 8.836 acres
Compensation completed		07 October, 2016

1.5.2.8. Grievance Redress Mechanism

The grievance redress mechanism based on the existing governance structure involving the GeogYargayTshogchung and the Dzongkhag YargayTshogde, has been formed with members from the Dzongkhag Administration, THyE and Geog Administration. This will allow affected households not satisfied with the proposed compensation and lease scheme to submit their grievances.

To activate the committee, a meeting was held to discuss on functions of the committee. The meeting was held on 07 October, 2016. Till date the committee has not received any complaints from the stakeholders. The community too does not have any grievance towards the project and indeed are happy for the land development cost and the freedom to choose substitute land provided to them.

1.5.3. Community Development Programme

As per the Resettlement Plan (RP), The Project in consultation with PAP and Geog representatives, committedNu. 16.40 million (excluding 10% contingencies) for Community Development Programmes (CDP). During THyE's15thTHyE Board Meeting, a sum of Nu. 15.15 million was approved for an additional proposal submitted by the Geog administration.

The Proposed Community development programs

a. Blacktopping of the Tangsibji Farm road from the national highway till NamgayChholing CPS. During the mass public consultation meeting on December 27, 2014, the Project agreed to Blacktop Tangsibji Farm road till NamgayChholing Community Primary School, which will benefit over 77 households. The blacktopping of 2.8 km road was awarded as a package to Adit-III access road construction and has been completed.

b. The blacktopping of additional 2.55 km farm road at Tangsibji was awarded in December 2015 to M/s Bikay Construction and is ongoing.

Figure 4.1 Blacktopped farm road at Tangsibji

Figure 5.1 Base work of additional 2.5 km blacktopping

c. Construction of a Temple and two vegetable outlets. THyE has disbursed the approved amount of Nu. 1.4 million for construction of the Temple and two vegetable outlets for which

a Letter of Understanding was signed on 30th December, 2015 between the Geog Administration and THyE.

Figure 6.1 Temple at Nyala

d. Study tour for geog officials involved in project services which was not approved by Gross National Happiness Commission (GNHC).

e. Purchase of an ambulance; the project at this point do not envisage procuring an ambulance due to availability of the facility with main contractor. The contractor has currently two ambulances.

f. Establishment of Tsogpas' offices; THyE furnished Tsogpas' office which shall benefit the Geog Administration during the meeting and consultation with the Chiwog people.

g. THyE, with the assistance from contractors, contributed 30 cement bags to Tshangkha Central School for constructing footpaths and flower pots and developing their Botanical Park in the school campus for aesthetic and educational purpose.

h. Due to insufficient class rooms, students were taught in a tent pitched outside the class which requires proper flooring. THyE contributed material for development of the class floor.

i. THyE contributed Nu.1.0 million for construction of stupa at Tashiling Lhakhang.

Figure 7.1 Class room at Tsangkha and Tashiling Lhakhang

1.5.4. Assisting the community in tackling human-wildlife conflicts

Wild boars are the main predator to the crops of farmers causing much hardship and financial loss to farmers. To help reduce this conflict with wildlife, THyE had a discussion with the Geog Administration on electric fencing of agriculture lands. During a meeting on October 27, 2015 it was mutually agreed between the Forest Territorial Division, Dzongkhag and Geog Administration that electric fencing system shall be implemented by Department of Forest and Park Services for which Nu.1.5 million was approved. The JSWNP has also requested for funding for electric fencing at two villages, Kela and Chendebji, falling under park, on 19 February, 2016. After revision by THyE, the proposal for electric fencing at Kela village was not recommended since it does not fall in the project area.

1.5.5. Income of project people

During the meeting held in September, 2016 with the local people of Tangsibji, the participants said that they benefitted from the project with the black topping of the farm road to Tangsibji village. This has made it very easy for them to sell their farm produce. Before the project, farmers would carry their produce to sell at Tsangkha but now because of the improved road conditions, project staff and visitors could drive right down to their village to buy farm produce and so they do not have to carry these anymore. Also, with increase in number of project staff at site, they can easily sell their farm produce and do not have to spend hours on the roadside trying to sell these.

At the dam site, a number of temporary sheds have been constructed with new shops and restaurants that cater to project staff and temporary workers.

Figure 8.1 Business developments due to project construction

With about 324 contractor's worker and 115 THyE's employee, there is certainly a boost in economy of local people through grocery and vegetable business, small contracts and wages.

1.5.6. Other Corporate Social Responsibilities

- ✓ Tshangkha Chiwog has 25 households and almost every household has a nursery from which they earn income in addition to the sale of cash crops such as potatoes. To enhance income generation, THyEpurchased 10,000 seedlings from the APs and planted these in their community forest and the project area. Further, PAPs were hired to plant these seedlings along the access roads in the project area and also during the survey works carried out in 2015.

- ✓ Nu. 10,000 was contributed to Tsangkhaon 2nd June, 2016 for plantation. All the seedling were purchased from the private nurseries to help generate income to the PAPs.

- ✓ Due to long distance from school to home, students of the community are provide transportation to and from school. Some students are transported from Tangsibji to Tsangkha Central School and other group from Nyala to Chendebji Primary School.

- ✓ Due to access road construction at Power House, the falling boulders and muck has affected arable land. To intervene the problem caused by the access road contractor, the affected household shall be compensated as per the crop compensation rate by the contractor. The contractor was notified for the same.

- ✓ The community primary school at NamgayChholing, Tangsibji was abandoned while consolidation of schools to Tsangkha Central School. THyE in agreement with Geog Administration renovated all the buildings and occupied the vacant houses as office and quarters to Head Race Tunnel (HRT) Division.

Figure 9.1 School after renovation

1.5.7. Environment Management Plan

1.5.7.1. Panel of Experts

To monitor implementation of the EMP and Resettlement Plan an Environmental Expert and Social Development Expert were appointed as External Panel of Experts. They serve as independent consultants to THyE by monitoring the implementation of environmental impacts and recommending appropriate mitigation measures.

The social experts is required to visit project sites to assess resettlement impacts, mitigation measures, and conduct consultations with AP to ascertain their views on RP implementation. The environmental expert is required to assess the performance of THyE and DGPC and the contractors in terms of implementation of environmental mitigation and monitoring measures specified in the EMP.

In line with their Terms of Reference, the Panel of Experts (PoEs) visited the project site four times; February 26-28, 2015; April 19-25, 2015 and November 15-22, 2015, 11-15 September, 2016. They also consulted relevant stakeholders to record their concerns and expectations. No adverse issues were highlighted in the report.


Figure 10.1 Consultation by Social Development Expert

1.5.7.2. Minimizing and Mitigation of impacts from construction works

a. Approval and Collaboration with Department of Forest and Park Services:

Prior to commencing road construction, the Project approached the Divisional Forest Officer under the Department of Forest to identify and mark all trees falling along the proposed road alignment. This was systematically conducted for all access roads, with the contractor and his engineer working closely with the forestry field staff. For an activity to begin forest personnel is always involved to enable him keep account for tree fallen and to recommend any measure to minimize tree felling.

Indiscriminate muck dumping was prevented through Environment-Friendly Road Construction Methodology allowing cut-and fill method. The destruction on vegetation was minimized except at inevitable location where the topography was steep and slide prone areas.

To prevent unapproved tree felling, contractors for access road construction were penalized as per the Waste Prevention and Management Act, Biodiversity Act and Forest and Nature Conservation Rule of Bhutan. Such enforcement of law shall not all prevent repeated offence but shall also encourage other contractors to abide by all rules and regulation concerning conservation and promote sustainable development.

b. Environment Friendly road construction

The construction methodology followed for access road was cut-fill which caused minimum damage on environment due to mucking. While passing water bodies culverts and cause ways were constructed to prevent pollution. Drainage and support structures were provided at required locations.

Figure 11.1 Access road constructed with less damage on environment

Figure 12.1 Retaining walls along access roads

Figure 13.1 Hume pipes, and drains to divert streams along access roads

c. Compensatory afforestation

To compensate for the loss of forest cover, the EMP had provisioned over Nu.26 million for compensatory afforestation of 624.34 acres, the impacted land for access roads has decreased from expected 43.940 acres to 19.652 acres. Therefore, compensatory afforestation (twice the impacted area).shall be carried out only for 39.304 acres. For the other area like muckdump site and contractor construction facilities actual affected land is not know at this stage and shall figure out accurately after all the construction works are established and resurveyed.

THyE has approved a sum of Nu. 9.0 million for the initial phaseof compensatory afforestation to Department of Forest and Park Service (DoFPS), for which a MoU was signed under which THyE provides a grant of Nu. 15.8 million to Gross National Happiness Commission (GNHC) to finance "***Compensatory Afforestation/Reforestation along Trongsa valley*** for the period beginning July 2016 till June 2019 for implementation to begin from 2017. The agreement was signed in August 2016. Under the agreement all plantation and land Management will be prioritized in project affected Geogs and shall be carried out in other Geogs only if grantee could not find suitable area in the project area. Priority is to be given to initiate land management works along the slopes along the newly constructedaccess roads and the muck dump sites. Under this agreement the project has also agreed to finance procurement of equipments (camera, laptop and printers), a vehicle and extension kits to facilitate delivery of services. The DoFPS is required to submittechnical narrative and financial progress reports semi-annually to THyE as well as an audited annual financial statement after all works are completed. The compensatory afforestation works are expected to commence in 2017. The MoU is attached at **Annexure-I**.

Figure 14.1 Seed broadcasting at surge shaft and plantation at Power House access road, 2015

Along the slopes of the access road to the Power House and Surge Shaft, grass seed were broadcasted, stem cutting planted and 3,000seedlings of *Cupress* sp were planted in July 2015, however, the survival rate was less due the then undergoing access road construction, slides

and heavy rainfall. With completion of all access roads at the end of 2015 grass seeds were broad casted again from 17-22 May at Adit-I, II, III , IV, V and Surge Shaft.This was an attempt to stabilize the slopes along the access roads but unfortunately the growth of these was hampered during the monsoon rains.

Figure 15.1 Seed broadcasted and plants survived, 2016

d. Plantation in community forest.

A community forest is managed by community forest group who is represented by a member from each household. With the damage to trees done by stringing of 33 kV distribution line to Adit-III and also to enhance community forestry, THyEin coordination with community forest group has also planted 4,000 seedlings in Tangsibji Community Forest and 4,000 seedlings in Tsangkha Community Forest.

All the seedlings are purchased from the private nurseries owned by the PAPs at Tsangkha thereby contributing also to their income.

Figure 16.1 Plantation at Community Forests

1.5.7.3. Conservation Plan for Floral Species

a. Rescue and conservation of rare and endangered species prior to and during construction

A Memorandum of Understanding (MoU) was signed between the National Biodiversity Centre (NBC), Ministry of Agriculture and THyE for rescue of rare, endangered, economically important species, from Nikachhu project site, on December 08, 2014. The purpose of the MoU was to enable the project to augment baseline floral data in the project area and to rescue threatened or economically importantspecies that may be damaged or destroyed during project construction. Further, seed collection of floral species is also done to conserve and propagate it in the laboratory atSerbithnag, Thimphu. Since then three floral surveys and rescues were conducted by the NBC at the project site. The project with NBC has completed in the end of December, 2016. The greatest achievement of the project shall be the floral field guide which shall be published in the mid of 2017. Under the project, NBC has also taken up initiative to build capacity of local forester in seed collection methodology and taxonomy. Herbarium collection are also done for various floral species and maintained with NBC.

Table 13.1 Details of floral survey and rescue

Survey/Rescue	Date	Remarks
1st survey and rescue	February 26-March 06, 2015	Documentation of existing floral diversity of the Nikachu hydropower project sites.
2nd survey and rescue	April 09- 13, 2015	Rescued 14 species of Orchids.
3rd survey and rescue	August 19-30, 2015	18 plant species were collected and rescued.

Figure 17.1 Floral species rescued from project sites

In total 32 plants species were rescued from all the project sites. The rescued floral species are conserved ex-situ as living collection at the Royal Botanical Garden, Serbithang, Thimphu.

Figure 18.1 Orchid species conserved in Orchidarium at Serbithang, Thimphu.

The project also funded the construction of a green house by NBC to house the rescued species.

Figure 19.1 Green House funded by THyE for conservation of rescued floral species

b. Establishment of a Botanical Garden

As a part of MoU signed with GNHC and DoFPS, THyE approved contribution of Nu. 3.6 million for construction of a Botanical Garden at Tingtibi during the 15th Board Meeting on October 30, 2015. However, the DoFPS in a meeting held on 15 March, 2016, has decided to review and reprioritize the EMP budget allocated for Biodiversity Conservation.

With transfer of Trongsa Forest Range from Zhemgang Territorial Division to Bumthnag Territorial Division, a meeting was held on 03 October, 2016 during which THyE was appraised by the new Forest Division to re-appropriate the grant fund. The Nu. 3.6 million has been not diverted towards construction of Orchidarium at Tangsibji instead of Botanical Garden at Tingtibi. As initiation to this activity, a small Orchidarium was built at GongsarDumra, a garden created in tribute to the first King of Bhutan, where orchids from Nikachhu Project area are housed.

1.5.7.4. Rescue of Wildlife

As per the EMP, the project would initiate the rescue and release of wildlife species encountered during construction works. For this the contractor will be required to contact the Park office in case any wildlife are encountered, or injured by accident during construction works. The rescue, treatment, and release of wildlife will then be conducted as per protocols followed by the Department of Forest and Park Services. To have a broader positive impact on wildlife conservation and to make their rescue easier, THyE has expressed the willingness to support establishment of rescue center at Tsangkha managed by Jigme SingyeWangchuk National Park (JSWNP) during the first Biodiversity Management Committee, renamed “Technical Committee for Biodiversity and Environment Management” meeting.

Todate there have been no reports of encounters or accidents to wildlife from Pre-construction works and initial main construction works.

1.5.7.5. Institutionalization of a Biodiversity Management Committee

Biodiversity Management Committee (BMC) was constituted for effective implementation of Biodiversity Conservation Programme enlisted in EMP, with members from different stakeholders such as Forest Officers from the Wildlife Conservation Division, Jigme Singye Wangchuck National Park, Forest Territorial Division and Dzongkhag Forest Office, Zhemgang; National Biodiversity Center; Royal Society for Protection of Nature; Department of Livestock; and THyE. The first committee meeting was held from 2-4 February, 2016.

As decided during the first meeting of Technical Committee for Biodiversity and Environment Conservation (TCBEM), a new member from Watershed Management Division was also included. The member from Zhemgang Forest Territorial Division was replaced by Bumthang Forest Territorial Division. The second committee meeting was held on 03 January, 2016 during which the next committee meeting was scheduled in the first week of March. During the meeting each member shall contribute an idea on conservation plan deemed essential for THyE to implement. The committee shall prioritize a plan and implement the same.

1.5.7.6. Augmentation of baseline information

a. Floral diversity

The project contributed a sum of Nu. 3,607,075.00 (Ngultrum three million six hundred seven thousand seventy five) for the three surveys conducted by the National Biodiversity Centre from February to August, 2015.Through the surveys, theexisting floral diversity of the project site was documented. Another objective for the survey was to also explore possibility of seed banking of the floral species for ex situ conservation.

A total of 402 species belonging to 106 families were recorded. This included tree species belonging to 106 families, 37 orchid species, 6 bamboo species and 264 other
Herbaceous and shrubs species. An additional 201 species were recorded during the third floral diversity assessment. The report of third survey is attached at **Annexure-II**.

b. Aquatic diversity

To augment baseline data from the fish survey carried out in 2012, THyE approved the proposal for aquatic survey by the College of Natural Resource, Lobesa to study fish, butterfly and micro-invertebrates during the lean season. Preliminary survey and site selection was conducted from 27 December, 2015 to 20 January, 2016 wherein two stretches of Nikachhu river were selected; one stretch from dam till ChendebjiChorten and another between TsheringmaiDrupchhu and confluence. The actual survey was carried out 02-10 March, 2016. The team recorded presence of Brown trout and Snow trout in designated stretches of river.

During the second detailed survey carried out from late March-early April, 2016 , three species were recorded; *Salmo trutta*, *Schizithorax richardsonii* and *Creteuchiloglanis* sp. A total of 244 individuals were enumerated during the study period. *Salmo trutta* (Brown trout) was observed to be dominant species. The presence of *Schizithorax richardsonii*(Snow trout) was found restricted towards the lower zone due to presence of water fall towards Nikachhu.

During the survey period seven orders and 17 families of micro-invertebrates were recorded. The diversity and abundance of these micro-invertebrate also indicate good quality of water. The report is attached at **Annexure-III**.

Figure 20.1 samples of micro-invertebrates and fishes recorded by CNR

To augment the study carried out by CNR for duration of six months, The National Centre for Riverine and Lake Fisheries (NCRLF), Haa, under the DoL was approved to be appointed as the aquatic specialist to THyE due their expertise and availability of required equipments and man-power. A MoU was signed between Gross National Happiness Commission (GNHC), DoL and THyE for implementation of 'Conservation and Monitoring of Fishery inNikachhu' on 24 December, 2015 for duration of six years. The team from NCRLF carried out preliminary site selection from 06-17 February. The Nikachhu and Mangdechhuwas divided into four zones with numerous stations as in the map below:

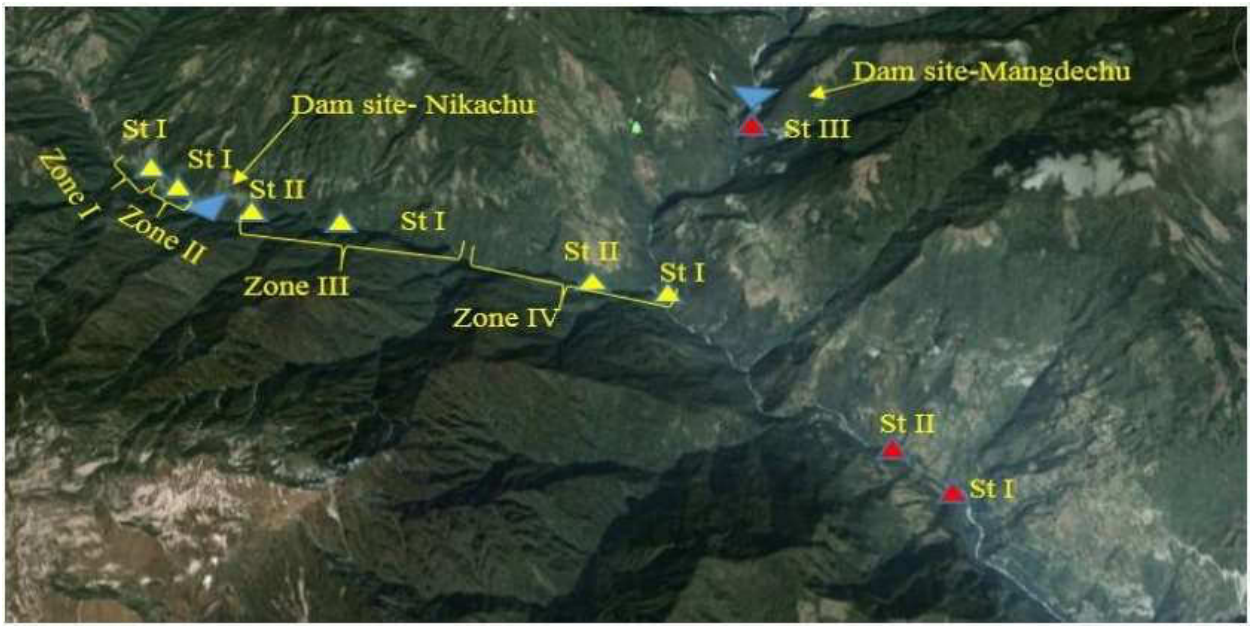

Figure 21.1 Zonation of sampling station

The fish survey was conducted from 21 March-01 April, 2016 and second survey from 26 October-05 November, 2016. During the first survey only two fish species were recorded; Snow trout at the confluence and all other zones are dominated by Brown trout. During the second survey only Brown troutwas recorded. The number of fishes has declined drastically in the second survey which could be probably due to decreased water temperature and high tubidity due to upstream Highway widening project.

Figure 22.1 Fish survey conducted at Nikachhuriver

The study also included assessment of micro-invertebrates. NCRLF recorded nine order and 20 families of micro-invertebrates adding three families to the one recorded by CNR. The reports are attached at **Annexure-IV**.

Figure 23.1 Micro-invertebrates sample from Nikachhu

As per the EMP, after the water diversion 10% (0.554 cumecs) of average lean flow has to be maintained to sustain the aquatic lives downstream. The discharge contribution by tributaries reflected in EMP was done through catchment ratio method and no ground truthing was done. Therefore to flow measurement was done to determine cumulative discharge contribution by the tributaries. The flow data were measured at the sites, depending on the nature of river flow using float method. This method does not seem reliable due to probability of human error and inaccessibility to most of the tributaries. Therefore, discussion were held with Department of Hydro Met Services (DHMS), Ministry of Economic Affairs (MoEA) to collect flow data installing gauge station and cross section method. A gauge was established at Chendebji and above Dam, however, it wasn't found feasible to install one at the confluence. The unfeasibility is due to flow and unsuitability of the section.Conversation is still under process with DHMS to find alternative method for flow measurement at confluence.

Figure 24.1 Flow measure using float method at accessible tributaries and main river

c. Butterflies

As a part of aquatic study taken up by CNR, a preliminary assessment of butterfly diversity was also carried out. The one season assessment has recorded eleven species belonging to four families. The detail is in the report attached at **Annexure-III**.

Figure 25.1 few butterflies captured in Nikachhu Project area

1.5.7.7. Anti-Poaching Measures

a. Worker and Public awareness

During the road construction period, to reduce the threat of poaching and educate workers and local residents on the need to protect biodiversity, an awareness program was conducted by THyE in collaboration with DoFPS on forestry rules and management from 18-19 April, 2016.

Figure 26.1 Awareness on forestry rules to local residents

To facilitate monitoring poaching in the project area, forestry staffs are provided with a vehicle with ownership transferred to Department of Forest and park Services.

Further to prevent un-authorized people from getting into the project area, check gates are made at each access road. This shall help check on people moving at night for poaching and illegal timber transportation.

1.5.7.8. Air and Water Quality Monitoring

As part of the EMP, noise, air quality, and water quality monitoring is required to be undertaken periodically to ensure minimal air and water pollution or damage to adjacent forests and water courses.

After the award of pre-construction work, air and water quality and noise levels were monitored on 15-16 July, 2015. The air quality parameters were all found within the standard while water quality parameters such as PH is 8.68 and 7.50 TU upstream of Dam and 8.44 PH and 10.50 TU downstream of dam (which was due to sediments from road cutting). While run off from the slope of roads is inevitable during the monsoon season, to reduce the impact on water quality, the contractor was asked to prevent falling of boulders and soil into the river.

Monitoring was also in September, 2016 by Druk Green Power Corporation. The ambient air quality parameters like RPM and TSPM are within the environmental standard, noise level during night is within limit while the level at Dam during day was found little higher than standard.

Table 14.1 Environment quality data vis a vis standard

Sl.no.	Parameters	Unit	Damsite	Tashiling	Standard
1	Air				
a.	Respirable Suspended particulate Matter (PM 10)	µg/m3	16.56	14.28	200.00

b.	Suspended particulate Matter		3.60	20.16	
c.	Total Suspended particulate Matter		10.71	24.99	100.00
2	Noise				
a.	Day	dB	69.80	64.80	65.00
b.	Night		44.60	41.20	55.00
3	Water		**U/S Dam**	**D/S Dam**	
a.	pH		8.35	8.00	6 to 9
b.	LDO	mg/l	7.94	7.97	4 to 6
c.	Conductivity	µS/cm	102.20	79.20	800 to 2000
d.	Chlorine	µg/m3	BDL	BDL	50 to 200
e.	Turbidity	TU	41.00	41.00	
f.	Arsenic	mg/L	BDL	BDL	0.01 to 0.05
g.	Water Temp	˚C	11.50	11.50	

The source of noise is mainly the machineries while drilling. Water quality parameter indicates good water quality. The quality monitoring report is attached as **Annexure-V**. The standard of water quality is attached as **Annexure-V (a)**.

1.5.7.9. Catchment Management

The EMP requires various catchment management programs comprising rapid classification of micro-watersheds, assessment of critical micro-watersheds, and implementation of management plans.

The Watershed Management Division (WMD) under DoFPS has been carrying out rapid assessment of watershed along Nikachhu since September 2015. The study identified three micro-watersheds as critical by function. While two of these are in SephuGeog under WangdueDzonkhag, one (TsheringmaiDrupchhu) is in the Project area. The WMD is currently preparing management plans for the two micro-watersheds under Sephu and shall not cover TsheringmaiDrupchhu. A meeting was held with WMD and other stakeholders from Forest and health office on 15-16 January, 2016, in WangduePhodrang wherein it was agreed that THyE will collabore with WMD for preparation of the management plan for the TsheringmaDrupchu micro-watershed.

The project conducted a field visit along the above mentioned watershed from 24-27 April, 2016, to assess the criticality through visual inspection. The watershed is pristine condition and the only concern is waste management. The issue shall be addressed in coordination with WMD and Forest Territorial Division during the preparation of management plan for the watershed.

1.5.7.10. Capacity Building

In December 2015 a hands-on workshop was provided by NBC in collaboration with Kew Garden, England to forest officials and field officers of various government agencies inThimphuto impart knowledge on seed collection from wild plants and its long term conservation.

NBC has also conducted capacity building in September 2016 in collaboration with UgyenWangchuk Institute for Conservation of Environment and Research (UWICER). The training was provided to local foresters to build capacity in plant taxonomy and herbarium collection.

1.5.7.11. Environmental strategies for worker camps and project sites

a. Worker site and camps

The project constructed 90 units of labour camps at various sites such as detailed below:

Table 15.1 labour camp at each site

Sl.No.	Project site	Number of Units (Nos)
1	Dam	20
2	Adit-I	10
3	Adit-II	10
4	Adit-III	10
5	Adit-V	10
6	Surge Shaft	10
7	Power House	20

These have been handed over to the contractor as part of the construction. These camps have been provided with separate officers' quarter, office units, drinking water, electricity supply, toilets and waste collection points. The temporary camps constructed during the access roads have been closed and handed over to the project.

b. Waste management

For proper waste management around project area, cleaning campaign and waste segregation was carried out from View Point till TsheringmaDrupchhu, in collaboration with Tshangkha Central School, on June 05, 2015 followed by THyE employees on 05 June, 2016 in celebration of World Environment Day.

Cleaning campaign was also done in collaboration with Geog and Dzongkhag administration on 09 December, 2016.

Figure 27.1 cleaning campaigns

Further, 25 nos. of garbage bins were also given to the Dzongkhag Administration, to be distributed wherever required. For waste management at project site contractors have installed dustbins to prevent workers littering. THyE have also placed several garbage bins at all the offices and quarters. In the area, where more waste generation is envisaged, such as schools, Geog Center and markets large double compartment wire-mesh garbage bins are placed. The waste from all the sites and community is collected twice a week for which a garbage compactor truck was procured.

Figure 28.1 Waste bins for waste management

For solid waste during the construction phase, THyE have asked Geog Administration to identify suitable area for landfill development in co-ordination with Forest Office. During the initial phase of project, THyE used the existing landfill at Chujapang owned by Dzongkhag Administration. A Garbage Compactor Truck purchased to facilitate collection of waste from the community and the project site.

1.5.7.12. Occupational Health and Safety

The implementation of occupational health and safety has been a challenge due to resistance by the main contractor, however, implementation is being gradually picked up. First step taken towards safety was use of Personal Protective Equipment (PPE), followed by sign boards, safety tapes where people need to watch out. Upon repeated reminder the contractor could recruit a safety officer in December 2016.

THyE has constituted a safety committee as required by Rules and Regulation on Occupational Health, Safety and prescribed by Ministry of Labour and Human Resource (MoLHR), Bhutan. The committee shall not only look into working safely but shall also provide importance to the health of all workers. The first committee meeting was held on 28 September, 2016.

Taking into account the risks of several minor injuries/accidents at workplace, THyE in collaboration with Trongsa Hospital has selected a First Aider from each project office and was trained in the field from 8-9 November, 2016. Each office is equipped with two First Aid Kits to render onsite treatment to minor injuries and illness.

Figure 29.1 First Aid training

As the underground tunnels move further the gas concentration increase in the confined area and shall lead breathing difficulty. To mitigate such impact on health, ventilation systems are installed.To improve visibility, proper illumination is provided in tunnels.

Figure 30.1 Ventilation system and illumination

1.5.7.13. Blasting impacts and protection of cultural sites

To monitor the impact of blasting on historical monuments and other important structures during construction, Vibration Monitoring Devices have been installed at five locations; Trongsa Dzong, Raven Resort, Tsangkha Central School, Tashiling Lhakhang and ChendebjiChorten. The structures were located near Power House, Surge Shaft, Adit-IV, Adit-III and Dam respectively.

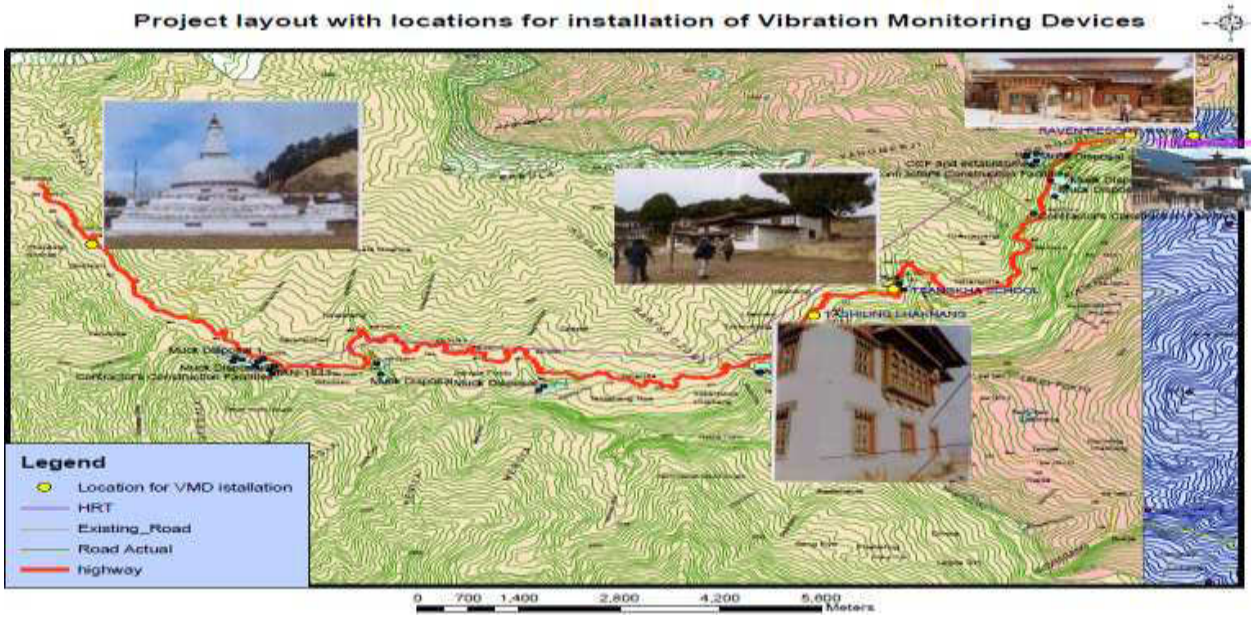

Figure 31.1 Shows five location where VMD are installed

The information and awareness about the vibration monitoring device was imparted to the Project Affected People.

Figure 32.1 Awareness of VMD to PAPs

The device will determine the magnitude of ground vibration as well as monitor noise levels at installation points. The maximum permissible vibration limit for historical monuments is taken as 2mm/s (standard taken from Director General of Mine Safety, Government of India) and maiximum air over pressure as 120 dB. When the device reads such figures, intervention shall be carried out by THyE to minimize the impact. Till date the threshold has not been detected.

Figure 33.1 VMD housed at five locations

To further avoid controversies and conflict with households near project area, mapping of house cracks were done in coordination with Center of Excellence in Vibration Monitoring and Thermographic Analysis (CoEVATA), Druk Green Power Corporation Limited and

GeogAdministration. This baseline information shall compared with the crack details should there be any complain regarding impact of blasting on the structures.

Figure 34.1 Crack mapping of structures at five locations

1.5.7.14. Unanticipated Impacts

The only unanticipated impacts occurred at the Adit-III access road construction site where a boulder damaged two stored house at Tangsibji, which has been rebuilt by the project with better facilities such as approach road, toilet, kitchen and water supply along with provision of household items to the satisfaction of the house owner.

Figure 35.1 Damaged house rebuilt

The house located about 200 meters below access road to Adit-III was damaged when the access road to Adit-III was under construction. After the second formation cutting was completed, towards the evening when all work has stopped, a boulder uphill of the access road rolled down and damaged the house which was not anticipated during the planning stage of the project. The loose boulder may be due to disturbance of slope and landscape during construction which may be aggravated by rainfall. The area has now been stabilized, loose boulders were been removed and proper slope maintained. A benching below the road is also made to retain loose falls, if any.

1.5.8. Monitoring

All the parameters of Environment Management Plan were complied. Besides THyE, the parameters are also monitored by DoFPS and National Environment Commission (NEC). Monitoring of project impacts on forest and biodiversity is carried out routinely by DoFPS. The National Environment Commission (NEC) monitors the project compliance annually. During the last visit there were no observations reported to THyE. Rather the project was commended on the way the access road was constructed which was implemented in an environmentally friendly manner.

1.5.9. Conclusion and Recommendations

THyE has completed most parts of Resettlement Plan including community development programs. While most Biodiversity Conservation activities are initiated the implementation of Environment Management Plan is a continuous process and shall require to be done till the operation phase of the project. The environment aspects are also strictly monitored by National regulators including Forest Territorial Division, Park, Panel of Experts and National Environment Commission. For the social aspects no grievances were recorded so far by the Grievance Redress Committee.

Grant Agreement

Between

Gross National Happiness Commission, RGOB

And

Tangsibji Hydro Energy Limited (THyE)

Grant Agreement Between
Gross National Happiness Commission (RGOB)
and
Tangsibji Hydro Energy Limited (THyE)

Whereas the Tangsibji Hydro Energy Limited (THyE) desires to provide a grant to Gross National Happiness Commission (GNHC) to finance ***"Compensatory Afforestation/Reforestation along Trongsa valley*** as per the attached grant proposal and budget in Annexure B for the period beginning July 2016 through June 2019;

Whereas GNHC and its implementing agency, the Department of Forest and Park Services, Ministry of Agriculture and Forests hereafter called the "Grantee" is ready and willing to implement the grant for the purpose granted;

Now, therefore, THyE and the Grantee, hereafter called the "Parties" here to agree to the following terms and conditions:

A. General:

i) THyE shall finance the agreed budget of Nu. 15.8 million (Nu. Fifteen million eight lakhs) only as per the breakdown in Annexure A.

ii) For project administration purposes, this grant shall be assigned a FIC and all funds shall be routed through this FIC;

iii) Grantee shall acknowledge the financial support of THyE for all activities supported under the current grant, including any publications produced or disseminated wholly or in part with THyE's grant funds;

iv) Grantee will maintain intellectual property rights of all research activities funded under this grant, but shall obtain the THyE's written permission if it wishes to use this project's materials for commercial purposes;

v) Plantation and Land Management shall be prioritized in Project Affected Geog and shall be carried out in other Geogs should the Grantee not find suitable area in the Project Area (all areas to be specified and agreed between THyE and grantee before implementation).

vi) The Grantee shall initiate Land Management works along the slope of access roads to the 118 MW Nikachhu Hydropower Project sites and also the muck dump sites.

vii) The equipments (camera, laptop and printers) shall be procured by THyE and distributed each to Chendebji FMU, Trongsa dzongkhag forestry and Trongsa Range. The equipments shall be institutionalized.

viii) THyE shall procure a vehicle and provide transportation to Grantee only when it renders service for THyE.

TANGSIBJI HYDRO

ix) Extension kits shall be procured by THyE for the field officials of Grantee.

x) During the course when the Grantee provides service to THyE the DSA shall be borne by THyE subject to approval by supervisor of the officer.

B. Disbursement and accounting:

xi) THyE shall disburse the funds annually based on the annual budget breakdown in Annexure A.

xii) Grantee and its implementing agencies shall maintain Books of Accounts in accordance with the Financial Manual of the Royal Government;

xiii) THyE shall have access to the Books of Accounts maintained by the Grantee and its implementing agencies if/whenever required to do so;

xiv) THyE will sanction additional funds available for compensatory afforestation, on completion of second year (2017), in order to compensate double the area taken up by the project.

C. Monitoring:

xv) The Grantee shall monitor the success of the plantation and prepare evaluation reports for further submission to higher authority;

xvi) The Grantee shall also monitor progress of other activities under the proposal.

xvii) In addition THyE and GNHC shall also monitor to ensure that the funds earmarked are used for the stated purposes.

D. Reporting:

xviii) Grantee and its implementing agencies shall submit an elaborate technical narrative and financial progress reports semi-annually to THyE as per the fund disbursement schedule agreed to under Article (v) above. The reports shall provide complete information on the progress and issues, if any;

xix) Grantee shall submit an audited annual financial statement to the THyE as and when Royal auditing is done;

xx) At the end of Project period, the unspent grant balance for each activity shall be returned to the THyE;

xxi) Within three months of conclusion of the grant (i.e. by 30/6/2019), Grantee and its implementing agencies shall prepare and submit to the THyE a draft implementation completion report.

E. Termination:

xxii) THyE shall terminate the grant if (a) there are significant deviations from the approved proposal, and/or (b) project implementation does not commence within six months from the date of signing the agreement;

TANGSIBJI HyDRO

xxiii) The THyE reserves the right, to discontinue or suspend grant funding if (a) the progress reports required are not submitted in a timely manner by the Grantee, (b) grant funds have not been used for their intended purposes or have been used inconsistent with the terms and conditions of this agreement, (c) THyE is not satisfied with the progress of the activities funded by the grant, and/or (d) the purposes for which the grant was made cannot be accomplished;

F. Project Extension:

xxiv) The THyE will consider giving additional available funds for compensatory afforestation works if the planned activities are implemented successfully.

xxv) If in case the allotted fund balance remains at the closing date, the project may be extended one year as "no cost project extension" without any financial obligation.

G. Final Authority:

xxvi) Any breach of the contract terms and conditions by either of the "Parties" shall be taken to the GNHC and THyE board for necessary action.

H. Duration and Effectiveness:

xxvii) The agreement shall cover the period starting from date of grant agreement signing to June, 2019.

xxviii) The agreement shall be effective from the day of signing of this grant agreement by the parties involved.

Managing Director
Tangsibji Hydro Energy Limited (THyE)
Tangsibji

Secretary
Gross National Happiness Commission
Thimphu

Implementing Agency:

Director
Department of Forests and Parks Services
Thimphu

TANGSIBJI HYDRO

Write up for the implementation of Tangsibji Hydro Energy Limited support fund for 2016-2019 under Tangsibji Gewog by Trongsa Dzongkhag Forestry.

1. Compensatory Afforestation program

Over the years the gewog has the highest percentage of forest cover with 25.70% conifer forest, 51.90 broad leaf forests and 9.90% Scrub forest. However, because of the two major hydro projects the gewog lost a huge area of forest cover. Nevertheless, the forest damages and vegetation destruction has been compensated partially through the compensatory plantation program supported by the Mangdue chu hydro power project. With the upcoming of the Tangsibji Hydro Power project, which falls completely within this gewog jurisdiction the massive damages to the forest could be visible. So in order to compensate the state forest lost for the construction of this hydro power projects it is felt necessary to carry out the compensatory and enrichment plantations in the barren and degraded forest areas.

1.1 Plantation in Barren Area (1.5 million)

As per the work plan submitted earlier this gewog has identified the barren and over grazed state forest land measuring about 33 hectares for plantation during the financial year 2016-2018. The site was chosen at Dorji Geonpa under Tangsibji gewog in consultation with the general public of Tangsibji gewog and the social clearance obtained from the nearby public. The identified site is completely barren and was earlier the Tsamdo for few local villagers, however later it was compensated by the Dzongkhag Tsamdo compensation committee.

#	Gewog	Location	Unit	Physical target	Proposed budget(M)	Remarks
01	Tangsibji	Dorji Geonpa	Ha	16	1.5	
	Total			**16**	**1.5**	

1.2 Plantation in the Community Forest and Water source protection (2.0 million)

Under this program covers the 06 community forests under Tangsibji geog measuring an area of 542 hectares of forest but mostly barren and covered with the scrubs and non timber species. The present forest needs to be refill with the fast growing timber species and that are beneficial to the local CF user group. The CF plantation will be carried out in the five chiwogs i.e Nyala/Drangla, Chendebji, Tangsibji, Tshangkha and Kella respectively.

About 05 water sources were found critical and that needs our intervention to protect especially the one which is affected by this upcoming hydro power project. One of the best examples is the Tsheringma Drupchu, which earlier was sufficient for drinking purpose for local village and cattle downstream but due to establishment of Project colony, it has been difficult and sometimes

scarce for even the travelers to drink. Therefore it is found necessary to protect the water source at this time of period.

1.3 Plantation Maintenance (0.90 million)

The plantation maintenance is very important for the successful plantation. The plantation maintenance works will be executed as per the norms and standards of the plantations developed by the Department of Forests and Park Services. Therefore, a sum of Nu. 0.9 million is proposed.

1.4 Training on seedlings raising to private owners (0.1million)

General public residing within this project areas were more or less depended on forest base d projects. They have been producing tree saplings from the forest nurseries at Tshangkha village and so far 13 households have registered with the Dzongkhag. At an average from the past 5 years record, they have been producing saplings between 50000- 70000 annually and meeting the seedlings target to almost four to five Dzongkhags.

Therefore to further improve and have good quality seedlings, it's necessary for the project to support the nursery operators on technical inputs like providing timely workshop, training and if possible the study tour within the country as well as nearby Indian state.

The gewog has also about 136 nos. of applicants requesting for private forest registration and about 23 households which have been already been issued with the PF certificate during the past years. During the financial year we have submitted about 18 applications for approval. Based on the past and present status it's found right time for us to support in terms of input supply and on technical grounds so that we can indirectly meet the goal of protecting 60% forest cover.

Most of the compensatory plantation seedlings are bought from private nurseries it is important to train the techniques of mother tree selection, time of seed collection, seed treatments, seed storage, sowing methods and seedling production techniques. Training is very essential to produce quality forests tree seedlings on time and needs. If there is sufficient fund the training to all nurseries owners is must for quality seedlings production.

2. Land Management within Tangsibji Geog Area (0.60 million)

The lands within this area are mostly susceptible to land degradation, landslides, soil erosion and loss of the fertile top soil. Over the years the geog has experienced the major challenges for reviving this critical area but due to shortage of fund the land management works could not be initiated. Moreover the land management activity needs to be focused especially in the 05 Adit locations of Tangsibji Hydro energy limited.

In few cases, the land management works needs to be done in the public private land that are affected by the construction work of the project. Beside land management works, land management campaign will be given to the local people of Tangsibji, Trongsa.

TANGSIBJI HyDRO

Write up for Trongsa Range Office and Chendebji FMU, under Zhemgang Forest Division
June 2016

1.Background

Watershed management is a multidisciplinary task and has multiple benefits. While it is vital to manage the upstream catchments with good vegetation cover to minimize downstream consequences, it is imperative to limit human activities and developments in order to avoid increased sediments that affect regulated water supply to hydropower plants. Although rich forest cover in Bhutan equates for rich water resources for multiple uses including hydropower development, we must be mindful of the challenges facing watershed management in Bhutan. As a part of watershed management, it is important to incentivize upstream communities including rangeland communities in protecting water catchments. Through incentives and benefits these communities derive, they will learn to appreciate environment and support in conservation of forests and watersheds.

The project is proposed to be funded by the Tangsibji Hydrop Energy Limited (THyEL) within the ambit of Environmental Management Programme of the project to mitigate and reduce the negative impacts and conserve the biodiversity and ecosystem services.

2. Rationale for the project

Nikachu is one of the rivers in the country and it has huge potential for hydro power generation. The construction of Tangsibji hydro energy plant in Nikachu basin has already commenced and it is going to economically benefit the country once completed. However, it is important to look at impacts the Tangsibji project is going to impose to the environment and communities in the watershed area. To mitigate the negative impacts of hydro power project in Tangsibji, ensure quality and sustained flow of water, and improve the livelihood of communities in the watershed, it is crucial to sustainably manage the forests and its resources in the upper and lower catchment areas of Tangsibji. No projects to address such issues have been implemented in the watershed area till now other then compensatory afforestation at Nyala in Trongsa initiate by Dzongkhag Forestry Sector with funding support from MHPA.

3. Project Location

Trongsa Dzongkhag (Divisional Forest Office, Zhemgang)

4. Project duration

The overall project duration is July 2016 – June 2019 (3 years). But different components may begin or end at different dates within the project period.

5. Establishment of plantation and its maintenance.

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Plantation within the catchment areas of THyEL will be done after details survey and estimate preparation. The priority will be given in immediate affected, degraded and barren areas. With available fund from THyEL the total area of plantation will be double the areas occupied or used by the project. The plantation creation at Kawdang (7 ha), maintenance of previously created plantation at Tshengaypang I & II (37 ha), Yarpanglingju (4 ha) and coming up of LMC at Adit I & II within Tangsibji areas. The total sum approved for the implementation of aforementioned activities is Nu. 7.5 million including training on seedlings raising.

6. Land Management and soil conservation.

The impacts from the THyEL project will have in whole area of Trongsa dzongkhag were the project works are carried. For this the land management works have to carry in entire areas of affected sites. For this, Nu. 0.6 million is allotted for Trongsa dzongkhag forestry and Nu.0.5 million for Trongsa range office and Nu. 0.4 million for Chendebji FMU office with total Nu. 1.5 million.

7. Seedling production and plantation management training.

Seedlings production technique is vital for the quality and quantity seedlings production from nurseries. For this, the training from head office and experienced forestry personal to the field implementing staffs and agencies is very important for better quality seedlings production for plantation within project area. Beside quality seedlings production, plantation methods and its management is top priority for better survival of the compensatory afforestation for this Nu. 0.2 million allotted from approved fund. It is very vital to allot sufficient fund for seedlings production and plantation management trainings.

8. Community based forest fire management.

The awareness campaign on forest fire rules, management strategies, prevention, basic safety, fire fighting, training, formation of community forest fire management group and procurement of forest fire fighting materials will be done by the end of the year, 2016 before the fire occurring season begins. Fire fighting is a challenging task for the forest fire fighters. Forest fire suppression is extremely dangerous and tedious. Local communities assist the forestry personnel to suppress the fire. Though people have knowledge on fire, they still lack some basic concepts. To adequately make the people understand the ecology of forest fire, basic safety and forest fire training will be imparted to local government officials and communities with fund of Nu.0.4 million.

9. Establishment of Botanical Garden at Bermoo.

The development of botanical garden like species relocation, plantation, walking paths, resting place, visitor information centre, sinages and relocation of orchid species from Nikachhu project,

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enhancement of Orchidarium and fern garden will be done during the year, 2017 with a approved sum of Nu. 3.6 millions. The Botanical garden will be both in-situ conservation of existing species of the area as well as ex-situ conservation of the plants recovered from MHPA, CHP-I and THyEL and transmission line clearings. The Garden will be partially funded by MHPA, CHP-I and THyEL will include infrastructure development such as visitor information centre, signages, raising of seedlings, relocation of important flora, walking trails, resting places etc. An Orhidarium will also be developed and house variety of Orchid species growing in the broadleaved forests. Overall, the botanical garden will serve as an ecological representative of sub-tropical to warm-broadleaved vegetation mainly for recreational and educational purposes. It will help promote public appreciation and understanding of plant life, gardens and inspire people to conserve the environment. Once established the Botanical Garden will generate revenue through visitor fees, donations and other sources to sustain its management. A detailed planning including design, features and business plan will be developed as part of this project.

10. Renovation of FMU Office cum resident.

The renovation of FMU office cum resident at Chendebji, fencing around the office and construction of entrance gate to office will be implemented in the year, 2017 with an approved sum of Nu. 1 million.

11. Monitoring of Chendebji Forest Management Unit (FMU).

The monitoring of FMU as per the FCMB, 2004 will be done in the year, 2016 and 2017 with the approved sum of Nu. 0.3 million. Chendebji FMU, which falls within the Nikachu watershed basin, with an area of 8,123.93 hectares has been under scientific forest management since 1996. It is in Trongsa Dzongkhag. The present management plan for the FMU will expire on 13th March 2017. Any activity carried out in the FMU will have direct implication on the Nikachu hydro power project because it is located in the catchment of Chendebji river or *Nyika Chhu* (one of the tributaries of Mangdechhu). The monitoring of FMU as per the FCMB, 2004 will be done in the year, 2016 and 2017 with the approved sum of Nu. 0.3 million.

12. Electric Fencing System (EFS)

Human wildlife conflict has become a chaos and confusion for both the government and the people. In a country where more than 75 percent of the people are farmers, the wild animals like Boar, Deer, Monkey; Elephant has established a national scourge. Round the year day and night farmers loose time and resources guarding their crops, yet every day they find crop damage in the field and half destroyed produce for families to feed. All over the country this scene is repeated for farmers whose livelihood is sole depended on agricultural farming. Thus, in the light of above grounds, the Electric Fencing System (EFS) has been developed collectively by various stakeholders of the government to reduce the crop damage to wild animals. In a move to address the Human wild life conflict, the EFS has been seen as a middle path to manage the Human wild life conflict in a better ways. Consequently, the same program of EFS has been proposed under

the environment management program of THyEL for 5 Gewogs of Trongsa and 1 Gewog of Wangdue. This program will covered 26 Chewogs in total with 130km of 5km average in every Chewog. The program will be implemented as per the guidelines of EFS issued by NPPC, DoA, MoAF with fund of Nu.1.5 million.

13. Monitoring and Evaluation

All activities will be monitored by the implementing agency on a regular basis with periodic monitoring conducted by the project team when necessary and team from the Department of Forests and Park Services, particularly from SFED. Beside annual report to the concern agencies time to time report when needed will be provided.

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TANGSIBJI HYDRO ENERGY LIMITED
(Developer of 118 MW Nikachhu Hydropower Project)
(An Undertaking of Druk Green Power Corporation Limited)

THyE/MD/Env/2016/ ৭২

04 July, 2016

The Director General
Department of Forest and Park Services
Thimphu

Subject: Approval of fund for Compensatory Afforestation under the proposal on enhancing conservation for sustainable management of Nikachhu.

Sir,

This is in reference to the letter received from your office vide no. SFED/Ptn/2-10/2015-2016/906 dated 29 June, 2016, regarding fund commitment by Tangsibji Hydro Energy (THyE).

The Forest Territorial Division, Zhemgang, had put up a proposal on enhancing conservation for sustainable management of Nikachhu on 29 July, 2015, and accordingly Nu. 15.80 million was approved for various activities during the 35th THyE Board Meeting held on 15 October, 2015. The same was already intimated to Forest Territorial Division vide letter no. THyE/MD/Env/2015/151 dated November 17, 2015. A copy of letter is attached herewith as **Annexure-I**.

The commitment letter for Nu.9.0 million was already provided to your office vide no. THyE/Env/01/2016/368 dated 08 March, 2016, and we further confirm your office that an additional Nu. 6.8 million will be funded, totaling Nu.15.8 million, for various activities detailed in **Annexure-II**.

In gratitude of your continued support.

Thanking you

Sincerely yours,

(Karma Chhophel)
Managing Director

Copy to:

1. Chief Forest Officer, SFED, Thimphu.
2. Chief Planning Officer, GNHC, Thimphu.
3. Chief Forest Officer, Territorial Division, Zhemgang.
4. Head, Environment Unit, THyE, Trongsa.

OFFICE OF MANAGING DIRECTOR
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Phone No. +975-2-339619/+975-2-337109 Fax No. +975-2-323853

Fund distribution for three years (2016-2019) under THyEL funding

A. Implementation by Trongsa Dzongkhag Forestry(Tangsibji)

Annexure A

Sl no	Activities	Year 2016	Year 2017	Year 2018	Year 2019	Total (Nu) in million
1	**Compensatory Afforestation**					
1.1	Plantation creation (16 Ha)	0.7	0.8	0	0	**1.5**
1.2	Community and water sources protection plantation (within 6 CF)	0.9	1.1	0	0	**2**
1.3	Plantation maintenance	0.5	0.4	0	0	**0.9**
1.4	Training on seeds and seedling raising to private nursery owners	0.1	0	0	0	**0.1**
2	**Land Management**					
2.1	Land management works	0.2	0.2	0	0	**0.4**
2.2	Land management campaign	0	0.2	0	0	**0.2**
	Total of A	**2.4**	**2.7**	**0**	**0**	**5.1**

B. Implementation by Trongsa Range Office

Sl.No	Work/Activities	Year 2016	Year 2017	Year 2018	Year 2019	Total (Nu. in million)
1	**Compensatory Afforestation**					
1.1	Plantation creation	0.8	0.9	0	0	**1.7**
1.2	Plantation maintenance	0	0.6	0.5	0	**1.1**
1.3	Seedling production and plantation management training to implementing agencies	0	0.2	0	0	**0.2**
2	**Land Management**					
2.1	Land management works	0.3	0.2	0	0	**0.5**
3	Community based forest fire management (under various gewog)	0.2	0.2	0	0	**0.4**
4	Electric fencing	0	1.5	0	0	**1.5**
5	Establishment of Botanical garden at Bermoo	0	3.6	0		**3.6**
	Total of B	**1.3**	**7.2**	**0.5**	**0**	**9**

C. Implementation by Chendebji FMU

Sl no	Activities	Year 2016	Year 2017	Year 2018	Year 2019	Total (Nu) in million
1	Monitoring FMU	0.1	0.2	0		**0.3**
2	Office cum resident renovation at Chendebji	0	1	0	0	**1**
3	Land management within Tangsibji area	0.2	0.2	0	0	**0.4**
	Total of C	**0.3**	**1.4**	**0**	**0**	**1.7**

D. Abstract of three offices under Bumthang Forest Division

Annexure B

Sl no	Activities	Year 2016	Year 2017	Year 2018	Year 2019	Total (Nu) in million
1	Trongsa Dzongkhag Forestry	**2.3**	**2.8**	**0**	**0**	**5.1**
2	Trongsa Range Office	**1.3**	**7.2**	**0.5**	**0**	**9**
3	Chendebji FMU	**0.3**	**1.4**	**0**	**0**	**1.7**
					All Total	**15.8**

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སོ་ནམ་ལྷན་ཚོག།
Ministry of Agriculture and Forests
National Biodiversity Centre
Serbithang: Thimphu

Report
Of the Final Field Work on the
Rescue of plants and rapid assessment of the floral diversity in the Tangsibjii Hydropower Limited project sites from 4th July to 12th August 2016

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Aims and objectives of the final field work

1. Documentation of existing floral diversity from the remaining project sites of the Tangsibji hydropower project.
2. To rescue prioritized plant species from the project sites for *ex-situ* conservation at the Royal Botanical garden, Serbithang

Introduction

Rescue, rehabilitation and ex-situ conservation of plant diversity are some of the main objectives of the Royal Botanical Garden, National Biodiversity Centre, Serbithang. Therefore, in line with objectives, National Biodiversity had initiated a joint rescue and restoration collection program for the threatened and rare plant species from the Tangsibji hydropower project sites.

During the final field work at Tangsibji hydropower project sites which was carried out from 4th July to 12th August 2016, resurvey and documentation of floral diversity in different Adits, Surge shaft and Dam sites which were not covered in previous expeditions were completed. Further, few species which had the potential for doing well at Serbithang were also rescued and conserved ex-situ as living collection at the Royal Botanical Garden, Serbtihang. List of floral diversity documented in this final field work as well as the list of species conserved as living collections are provided as annexures.

Results

22 live plants were collected and rescued during this final field work from Tangsibji hydropower project sites, based on the quantitative vegetation data from eight sites (5 Adits, Dame Site, Surge-Shaft and Power house). A total of 418 species belonging to 114 families were recorded including tree, seedling and ground layers. Floristically, the vegetation composed of 114 families (98 Angiospermous and 6 of Gymnospermous), 37 orchid species, 6 bamboo species, 20 ferns, 251 of other herbaceous and shrubs species.

Annex 1: List of plant species rescued and conserved ex-situ as living collection at Royal Botanical garden, Serbithang

SI.No	Scientific name	Family
1	*Bulbophyllum reptans*	Orchidaceae
2	*Dendrobium hookerianum*	Orchidaceae
3	*Dendrobium longicornu*	Orchidaceae
4	*Goodyera* falcata	Orchidaceae
5	*Dendrobium falconeri*	Orchidaceae
6	*Vandopsis undulata*	Orchidaceae
7	*Bulbophyllum* sp.	Orchidaceae
8	*Platanthera* sp	Orchidaceae
9	*Ione spcirrahata*	Orchidaceae
10	*Ione bicolor*	Orchidaceae
11	*Phalaenopsis taenialis*	Orchidaceae
12	*Eria* sp.	Orchidaceae
13	*Eria coronaria*	Orchidaceae
14	*Gastochilus* sp.	Orchidaceae
15	*Liparis* sp.	Orchidaceae
16	*Cryptochilus lutea*	Orchidaceae
17	*Anthogonium gracile*	Orchidaceae
18	*Eria graminifolia*	Orchidaceae
19	*Sunipia*	Orchidaceae
20	*Spathoglottis ixiodies*	Orchidaceae
21	*Ceropegia* sp.	Apocynaceae
22	*Begonia sp*	Begoniaceae

Some of the plants found in Tangsebjii Hydropower project sites

Rhododendron vaccinioides

Viburnum cornifolium

Actinidia strigosa

Philadelphous tomentosus

Mimulus nepalensis

Tetracentron sinense

Chirita sp

Nepeta lamiopsis

Eria graminifolia

Castanopsis tribuloides

Aristolochia griffithii

Monotropa uniflora

Annex 1.1: List of plant species recorded from Dam Site

Dam site			
SI.No	**Scientific Name**	**Family**	**Habit**
1	*Acer campbellii*	Aceraceae	Tree
2	*Acer taronese*	Aceraceae	Tree
3	*Aconogonon campanulatum*	Polygonaceae	Herb
4	*Aconogonon molle*	Polygonaceae	Herb
5	*Aeschynanthus sp.*	Gesneriaceae	Shrub
6	*Agapetes serpens*	Ericaceae	Shrub
7	*Ainsliaea aptera*	Compositae	Herb
8	*Alangium alpinum*	Alangiaceae	Shrub/Tree
9	*Anaphalis* sp.	Compositae	Shrub
10	*Arisaema jacquemontii*	Araceae	Herb
11	*Arisaema* sp.	Araceae	Herb
12	*Aristolochia griffithii*	Aristolochiaceae	Woody Climber
13	*Artemisia vulgaris*	Compositae	Herb
14	*Axonopus compressus*	Gramineae	Grass
15	*Asplenium* sp.	Malpighiaceae	Fern
16	*Begonia* sp.	Begoniaceae	Herb
17	*Berberis angulosa*	Berberidaceae	Shrub
18	*Berberis aristata*	Berberidaceae	Shrub
19	*Berberis* sp.	Berberidaceae	Shrub
20	*Betula alnoides*	Betulaceae	Tree
21	*Buddleja* sp.	Buddlejaceae	Shrub
22	*Bulbophyllum reptans*	Orchidaceae	Orchid
23	*Bulbophyllum* sp.	Orchidaceae	Orchid
24	*Carex* sp.	Cyperaceae	Herb
25	*Carpesium* sp.	Compositae	Herb
26	*Carpinus viminea*	Betulaceae	Tree
27	*Castanopsis tribuloides*	Fagaceae	Tree
28	*Cautleya gracilis*	Zingiberaceae	Herb
29	*Chirita* sp.	Gesneriaceae	Herb
30	*Clematis* sp.	Ranunculaceae	Climber
31	*Coelogyne nitida*	Orchidaceae	Orchid
32	*Conyza* sp.	Compositae	Herb
33	*Cyanotis vaga*	Commelinaceae	Herb
34	*Cynoglossum furcatum*	Boraginaceae	Herb
35	*Daphne bholua*	Thymelaeaceae	Shrub
36	*Daphnephyllum himalense*	Thymelaeaceae	Tree

37	*Dechesnea indica*	Lardizabalaceae	Herb
38	*Diaplazium esculatum*	Athyriaceae	Fern
39	*Digitaria ciliaris*	Gramineae	Grass
40	*Elaeagnus parvifolia*	Elaeagnaceae	Shrub
41	*Elatostema* sp.	Urticaceae	Herb
42	*Epigenium* sp.	Orchidaceae	Orchid
43	*Eurya acuminata*	Theaceae	Tree
44	*Fagopyrum dibotrys*	Polygonaceae	Herb
45	*Fagopyrum* sp.	Polygonaceae	Herb
46	*Fern* sp.	Pteridophytes	Herb
47	*Ficus* sp.	Moraceae	Climber
48	*Fragaria nubicola*	Rosaceae	Herb
49	*Galinsoga parviflora*	Compositae	Herb
50	*Galium aparine*	Rubiaceae	Herb
51	*Gamblea ciliata*	Araliaceae	Tree
52	*Gaultheria semi-infera*	Ericaceae	Shrub
53	*Gentiana capitata*	Gentianaceae	Herb
54	*Geranium nepalense*	Geraniaceae	Herb
55	*Girardinia diversifolia*	Urticaceae	Herb
56	*Goodyera* sp.	Orchidaceae	Orchid
57	*Grass* sp.	Poaceae	Grass
58	*Halenia elliptica*	Gentianaceae	Herb
59	*Hedera nepalensis*	Araliaceae	Woody climber
60	*Hemiphragma heterophyllum*	Scrophulariaceae	Herb
61	*Holboellia latifolia*	Lardizabalaceae	Shrub
62	*Houttuynia cordata*	Saururaceae	Herb
63	*Hydrocotyle himalaica*	Umbelliferae	Herb
64	*Hypercium* sp.	Hypericaceae	Shrub
65	*Ilex dipyrena*	Aquifoliaceae	Tree
66	*Juncus* sp.	Juncaceae	Herb
67	*Leucas ciliata*	Labiatae	Herb
68	*Ligustrum confortum*	Oleaceae	Shrub
69	*Lindera pulcherrima*	Lauraceae	Tree
70	*Lonicera* sp.	Caprifoliaceae	Climber
71	*Lycopodium* sp.	Lycopodiaceae	Fern
72	*Lyonia ovalifolia*	Ericaceae	Shrub/Tree
73	*Maddenia himalaica*	Rosaceae	Shrub/Tree
74	*Magonila campbellii*	Magnoliaceae	Tree
75	*Mazus* sp.	Scrophulariaceae	Herb

76	*Michelia doltsopa*	Magnoliaceae	Tree
77	*Mimulus nepalensis*	Scrophulariaceae	Herb
78	*Myrsine semiserrata*	Myrsinaceae	Shrub/Tree
79	*Neillia rubiflora*	Rosaceae	Shrub
80	*Nepeta lamiopsis*	Labiatae	Herb
81	*Oberonia* sp.	Orchidaceae	Orchid
82	*Ophiopogon* sp.	Convallariaceae	Herb
83	*Oplismenus compositus*	Gramineae	Herb
84	*Oxalis corniculata*	Oxalidaceae	Herb
85	*Parochetus communis*	Leguminosae	Herb
86	*Parthenocissus semicordata*	Vitaceae	Climber
87	*Peperomia tetraphylla*	Piperaceae	Herb
88	*Persea clarkeana*	Lauraceae	Tree
89	*Persea duthiei*	Lauraceae	Tree
90	*Persicaria runcinata*	Polygonaceae	Herb
91	*Persicaria* sp.	Polygonaceae	Herb
92	*Pilea* sp.	Urticaceae	Herb
93	*Plantogo erosa*	Plantaginaceae	Herb
94	*Pleione praecox*	Orchidaceae	Orchid
95	*Potentilla* sp.	Rosaceae	Shrub
96	*Pouzolzia* sp.	Urticaceae	Herb
97	*Primula* sp.	Primulaceae	Herb
98	*Primula denticulata*	Primulaceae	Herb
99	*Pseudognaphalium affine*	Compositae	Herb
100	*Pteridium aquilium*	Dennataedtiaceae	Fern
101	*Pueraria peduncularis*	Leguminosae	Herb
102	*Pyrossia boothii*	Pyrolaceae	Fern
103	*Quercus lamellosa*	Fagaceae	Tree
104	*Quercus oxyodon*	Fagaceae	Tree
105	*Qurecus glauca*	Fagaceae	Tree
106	*Ranunculus* sp.	Ranunculaceae	Herb
107	*Rhaphidophora* sp.	Araceae	Herb
108	*Rhododendron arboreum*	Ericaceae	Tree
109	*Rhododendron edgeworthii*	Ericaceae	Shrub
110	*Rhododendron falconeri*	Ericaceae	Shrub/Tree
111	*Rhododendron grande*	Ericaceae	Shrub/Tree
112	*Rhododendron griffithianum*	Ericaceae	Shrub/Tree
113	*Rhododendron hodgsonii*	Ericaceae	Shrub/Tree
114	*Rhododendron kesangiae*	Ericaceae	Tree

115	*Rhododendron lindleyi*	Ericaceae	Shrub
116	*Roscoea alpina*	Zingiberaceae	Herb
117	*Rubia manjith*	Rubiaceae	Climber
118	*Rubus biflorus*	Rosaceae	Shrub
119	*Rubus calycinus*	Rosaceae	Herb
120	*Rubus nepalensis*	Rosaceae	Herb
121	*Rubus paniculatus*	Rosaceae	Climber
122	*Rubus* sp.	Rosaceae	Shrub
123	*Rumex nepalensis*	Polygonaceae	Herb
124	*Sambucus adnata*	Caprifoliaceae	Herb
125	*Sarcococca hookeriana*	Buxaceae	Shrub
126	*Senecio laetus*	Compositae	Herb
127	*Smilax myrtillus*	Smilacaceae	Shrub
128	*Smilax* sp.	Smilacaceae	Shrub
129	*Sorbus griffithii*	Rosaceae	Tree
130	*Sorbus wallichii*	Rosaceae	Tree
131	*Stellaria vestita*	Caryophyllaceae	Herb
132	*Sunipia* sp.	Orchidaceae	Orchid
133	*Swertia bimaculata*	Gentianaceae	Herb
134	*Symplocos dryophila*	Symplocaceae	Tree
135	*Symplocos glomerata*	Symplocaceae	Tree
136	*Symplocos lucida*	Symplocaceae	Tree
137	*Symplocos ramosissima*	Symplocaceae	Shrub/ Tree
138	*Symplocos sumuntia*	Symplocaceae	Tree
139	*Tetradium fraxinifolium*	Rutaceae	Tree
140	*Tetrastigma* sp.	Vitaceae	Climber
141	*Thalictrum* sp.	Ranunculaceae	Herb
142	*Trifolium repens*	Leguminosae	Herb
143	*Tsuga dumosa*	Pinaceae	Tree
144	*Tupistra nutans*	Convallariaceae	Herb
145	*Tupistra* sp.	Convallariaceae	Herb
146	*Unknown* sp.		Shrub/Tree
147	*Vaccinium* sp.	Ericaceae	Shrub
148	*Valeriana* sp.	Valerianaceae	Herb
149	*Viburnum erubescens*	Caprifoliaceae	Shrub
150	*Viola bhutanica*	Violaceae	Herb
151	*Viscum* sp.	Loranthaceae	Shrub
152	*Vitis heyneana*	Vitaceae	Climber
153	*Woodwardia unigemmata*	Lythraceae	Fern

154	*Yushania macophylla*	Gramineae	Bamboo
155	*Zanthoxylum nepalense*	Rutaceae	Shrub

Annex 1.2: List of plant species recorded from Adit-1

ADIT 1			
SI.No	**Scientific Name**	**Family**	**Habit**
1	*Acer campbellii*	Aceraceae	Tree
2	*Acer cappadocicum*	Aceraceae	Tree
3	*Aconogonon campanulatum*	Polygonaceae	Herb
4	*Aconogonon molle*	Polygonaceae	Herb
5	*Actinidia callosa*	Actinidiaceae	Shrub
6	*Agapetes serpens*	Ericaceae	Shrub
7	*Ageratina adenophora*	Compositae	Herb
8	*Agrimonia pilosa*	Rosaceae	Herb
9	*Ainsliaea aptera*	Compositae	Herb
10	*Alangium alpinum*	Alangiaceae	Shrub/Tree
11	*Alnus nepalensis*	Betulaceae	Tree
12	*Anaphalis* sp.	Compositae	Herb
13	*Angelica cyclocarpa*	Umbelliferae	Herb
14	*Anthogonium gracile*	Orchidaceae	Orchid
15	*Arisaema* sp.	Araceae	Herb
16	*Aristolochia griffithii*	Aristolochiaceae	Woody Climber
17	*Artemisia vulgaris*	Compositae	Herb
18	*Asplenium* sp.	Malpighiaceae	Fern
19	*Astilbe rivularis*	Saxifragaceae	Herb
20	*Bamboo* sp.	Gramineae	Bamboo
21	*Begonia* sp.	Begoniaceae	Herb
22	*Berberis aristata*	Berberidaceae	Shrub
23	*Berberis* sp.	Berberidaceae	Shrub
24	*Betula alnoides*	Betulaceae	Tree
25	*Bulbophyllum reptans*	Orchidaceae	Orchid
26	*Carpinus faginea*	Betulaceae	Tree
27	*Carpinus viminea*	Betulaceae	Tree
28	*Castanopsis tribuloides*	Fagaceae	Tree
29	*Cautleya gracilis*	Zingiberaceae	Herb
30	*Ceologyne nitida*	Orchidaceae	Orchid
31	*Chelianthes* sp.	Pteridaceae	Fern

32	*Cinnamomum* sp.	Lauraceae	Shrub/Tree
33	*Cirsium* sp.	Compositae	Herb
34	*Clematis* sp. 1	Ranunculaceae	Climber
35	*Coelogyne nitida*	Orchidaceae	Orchid
36	*Conyza* sp.	Compositae	Herb
37	*Cymbidium* sp.	Orchidaceae	Orchid
38	*Cynoglossum furcatum*	Boraginaceae	Herb
39	*Daphne bholua*	Thymelaeaceae	Shrub
40	*Daphnephyllum himalense*	Thymelaeaceae	Tree
41	*Dendrobium longicornu*	Orchidaceae	Orchid
42	*Dendrobium* sp.	Orchidaceae	Orchid
43	*Dichrocephala integrifolia*	Compositae	Herb
44	*Didymocarpus* sp.	Gesneriaceae	Herb
45	*Diplazium* sp.	Athyriaceae	Fern
46	*Duchesnea indica*	Rosaceae	Herb
47	*Edgeworthia gardeneri*	Thymelaeaceae	Herb
48	*Elsholtzia strobifera*	Labiatae	Herb
49	*Epigenium fusuces*	Orchidaceae	Orchid
50	*Eria coronaria*	Orchidaceae	Orchid
51	*Eria* sp.	Orchidaceae	Orchid
52	*Eria spicata*	Orchidaceae	Orchid
53	*Eurya acuminata*	Theaceae	Shrub/Tree
54	*Fern* sp.	Pteridaceae	Fern
55	*Fragaria nubicola*	Rosaceae	Herb
56	*Galium aparine*	Rubiaceae	Herb
57	*Gamblea ciliata*	Araliaceae	Tree
58	*Gaultheria fragrantissima*	Ericaceae	Shrub
59	*Gaultheria hookeri*	Ericaceae	Shrub
60	*Gaultheria tricophylla*	Ericaceae	Shrub
61	*Gentiana capitata*	Gentianaceae	Herb
62	*Geranium nepalense*	Geraniaceae	Herb
63	*Girardinia diversifolia*	Urticaceae	Herb
64	*Goodyera* sp.	Orchidaceae	Orchid
65	*Hackelia* sp.	Boraginaceae	Herb
66	*Halenia elliptica*	Gentianaceae	Herb
67	*Hedera nepalensis*	Araliaceae	Woody Climber
68	*Hemiphragma heterophyllum*	Scrophulariaceae	Herb
69	*Holboellia latifolia*	Lardizabalaceae	Woody climber
70	*Hypercium* sp.	Hypericaceae	Shrub

71	*Ilex dipyrena*	Aquifoliaceae	Shrub/Tree
72	*Impatiens* sp.	Balsaminaceae	Herb
73	*Ione* sp.	Orchidaceae	Orchid
74	*Leucas ciliata*	Labiatae	Herb
75	*Ligustrum confusum*	Oleaceae	Shrub/Tree
76	*Ligustrum* sp.	Oleaceae	Shrub
77	*Lindera* sp.	Lauraceae	Tree
78	*Lobelia* sp.	Campanulaceae	Herb
79	*Lycopodium calvatum*	Lycopodiaceae	Fern
80	*Lyonia ovalifolia*	Ericaceae	Tree
81	*Magonila campbellii*	Magnoliaceae	Tree
82	*Maianthemum oleraceum*	Convallariaceae	Herb
83	*Mazus* sp.	Scrophulariaceae	Herb
84	*Michelia doltsopa*	Magnoliaceae	Tree
85	*Michelia kisopa*	Magnoliaceae	Tree
86	*Michelia velutina*	Magnoliaceae	Tree
87	*Mimulus nepalensis*	Scrophulariaceae	Herb
88	*Myrsine semiserrata*	Myrsinaceae	Tree
89	*Neillia rubiflora*	Rosaceae	Shrub
90	*Nepeta lamiopsis*	Labiatae	Herb
91	*Oberonia* sp.	Orchidaceae	Orchid
92	*Oleandra pistillaris*	Olendraceae	Fern
93	*Otochilus sp*	Orchidaceae	Orchid
94	*Panax pseudo-ginseng*	Araliaceae	Herb
95	*Parthenocissus semicordata*	Vitaceae	Climber
96	*Persea clarkeana*	Lauraceae	Tree
97	*Persea duthiei*	Lauraceae	Tree
98	*Persicaria* sp.	Polygonaceae	Herb
99	*Phlomis* sp.	Labiatae	Herb
100	*Pilea* sp.	Urticaceae	Herb
101	*Plantago erosa*	Plantaginaceae	Herb
102	*Platanthera* sp.	Orchidaceae	Orchid
103	*Pleione humulis*	Orchidaceae	Orchid
104	*Polygonatum* sp.	Convallariaceae	Herb
105	*Potentilla* sp.	Rosaceae	Herb
106	*Pouzolzia* sp.	Urticaceae	Herb
107	*Pseudognaphalium affine*	Compositae	Herb
108	*Pteridium* sp.	Dennataedtiaceae	Fern
109	*Pteris* sp.	Polypodiaceae	Fern

110	*Quercus glauca*	Fagaceae	Tree
111	*Quercus lamellosa*	Fagaceae	Tree
112	*Quercus oxyodon*	Fagaceae	Tree
113	*Rhododendron arboreum*	Ericaceae	Tree
114	*Rhododendron edgeworthii*	Ericaceae	Shrub
115	*Rhododendron grande*	Ericaceae	Shrub/Tree
116	*Rhododendron lindleyi*	Ericaceae	Shrub
117	*Rhododendron vaccinioides*	Ericaceae	Shrub
118	*Rhus hookeri*	Anacardiaceae	Tree
119	*Ribes* sp.	Grossulariaceae	Shrub
120	*Rubia manjith*	Rubiaceae	Climber
121	*Rubus biflorus*	Rosaceae	Shrub
122	*Rubus calycinus*	Rosaceae	Herb
123	*Rubus ellipticus*	Rosaceae	Shrub
124	*Rubus paniculatus*	Rosaceae	Climber
125	*Rubus* sp.	Rosaceae	Climber
126	*Scurrula elata*	Loranthaceae	Shrub
127	*Senecio laetus*	Compositae	Herb
128	*Senecio scandens*	Compositae	Herb
129	*Smilax myrtillus*	Smilacaceae	Shrub
130	*Smilax* sp.	Smilacaceae	Shrub
131	*Solanum nigrum*	Solanaceae	Herb
132	*Sorbus griffithii*	Rosaceae	Tree
133	*Sorbus* sp.	Rosaceae	Tree
134	*Stachys* sp.	Labiatae	Herb
135	*Stellaria vestita*	Caryophyllaceae	Herb
136	*Strobilanthes* sp.	Acanthaceae	Herb
137	*Sunipia* sp.	Orchidaceae	Orchid
138	*Swertia* sp.	Gentianaceae	Herb
139	*Symplocos dryophila*	Symplocaceae	Tree
140	*Symplocos glomerata*	Symplocaceae	Tree
141	*Symplocos lucida*	Symplocaceae	Shrub
142	*Symplocos ramosissima*	Symplocaceae	Shrub/Tree
143	*Synotis wallichii*	Compositae	Herb
144	*Tetracentron sinense*	Tetracentraceae	Tree
145	*Tetradium fraxinifolium*	Rutaceae	Tree
146	*Thalictrum* sp.	Ranunculaceae	Herb
147	*Tsuga dumosa*	Pinaceae	Tree
148	*Tupistra* sp.	Convallariaceae	Herb

149	*Vaccinium nummularia*	Ericaceae	Shrub
150	*Viburnum cylindricum*	Caprifoliaceae	Shrub/Tree
151	*Viburnum erubescens*	Caprifoliaceae	Shrub
152	*Viburnum* sp.	Caprifoliaceae	Shrub
153	*Viola* sp.	Violaceae	Herb
154	*Viscum* sp.	Loranthaceae	Shrub
155	*Vitis* sp.	Vitaceae	Climber
156	*Zanthoxylum nepalense*	Rutaceae	Shrub
157	*Zanthoxylum* sp.	Rutaceae	Tree

Annex 1.3: List of floral species recorded from Adit-2

Adit 2			
SI.No	**Scientific Name**	**Family**	**Habit**
1	*Acer campbellii*	Aceraceae	Tree
2	*Acer cappadocicum*	Aceraceae	Tree
3	*Aconogonum campanulatum*	Polygonaceae	Herb
4	*Aconogonum molle*	Polygonaceae	Herb
5	*Actinidia strigosa*	Actinidiaceae	Shrub
6	*Agapetes incurvata*	Ericaceae	Shrub
7	*Agapetes serpens*	Ericaceae	Shrub
8	*Agapetes* sp.	Ericaceae	Shrub
9	*Ainsliaea aptera*	Compositae	Herb
10	*Alnus nepalensis*	Betulaceae	Tree
11	*Anaphalis* sp.	Compositae	Herb
12	*Artemisia vulgaris*	Compositae	Herb
13	*Astilbe rivularis*	Saxifragaceae	Herb
14	*Bamboo* sp.	Gramineae	Bamboo
15	*Berberis aristata*	Berberidaceae	Shrub
16	*Berberis* sp.	Berberidaceae	Shrub
17	*Betula alnoides*	Betulaceae	Tree
18	*Brassaiopsis mitis*	Araliaceae	Tree
19	*Buddleja asiatica*	Buddlejaceae	Shrub
20	*Buddleja* sp.	Buddlejaceae	Shrub
21	*Bulbophyllum reptans*	Orchidaceae	Orchid
22	*Bulbophyllum* sp.	Orchidaceae	Orchid
23	*Carex* sp.	Cyperaceae	Grass
24	*Carpinus viminea*	Betulaceae	Tree
25	*Castanopsis tribuloides*	Fagaceae	Tree

26	*Cautleya gracilis*	Zingiberaceae	Herb
27	*Chelianthes* sp.	Pteridaceae	Fern
28	*Conyza* sp.	Compositae	Herb
29	*Crassocephalum crepidoides*	Compositae	Herb
30	*Cyperus* sp.	Cyperaceae	Grass
31	*Daphnephyllum himalense*	Thymelaeaceae	Tree
32	*Dendrophthoe falcata*	Loranthaceae	Shrub
33	*Desmodium* sp.	Leguminosae	Shrub
34	*Dichrocephala integrifolia*	Compositae	Herb
35	*Docynia indica*	Rosaceae	Tree
36	*Edgeworthia gardeneri*	Thymelaeaceae	Shrub
37	*Elaeagnus pyriformis*	Elaeagnaceae	Shrub
38	*Elsholtzia fruticosa*	Scrophulariaceae	Shrub
39	*Epigenium* sp.	Orchidaceae	Orchid
40	*Eria* sp.	Orchidaceae	Orchid
41	*Eupatorium marei*	Compositae	Herb
42	*Eurya acuminata*	Theaceae	Shrub/Tree
43	*Galinsoga parviflora*	Compositae	Herb
44	*Gamblea ciliata*	Araliaceae	Tree
45	*Gaultheran fragratissima*	Ericaceae	Shrub
46	*Geranium nepalense*	Geraniaceae	Herb
47	*Hedera nepalensis*	Araliaceae	Woody Climber
48	*Hedychium aurantiacum*	Zingiberaceae	Herb
49	*Hedychium* sp.	Zingiberaceae	Herb
50	*Holboellia latifolia*	Lardizabalaceae	Shrub
51	*Ilex dipyrena*	Aquifoliaceae	Tree
52	*Impatiens* sp.	Balsaminaceae	Herb
53	*Indigofera dosua*	Leguminosae	Shrub
54	*Juncus* sp.	Juncaceae	Herb
55	*Leucas ciliata*	Labiatae	Herb
56	*Leycesteria formosa*	Caprifoliaceae	Shrub
57	*Ligustrum* sp.	Oleaceae	Shrub
58	*Lindera pulcherrima*	Lauraceae	Tree
59	*Lobelia* sp.	Campanulaceae	Herb
60	*Lycopodium calvatum*	Lycopodiaceae	Fern
61	*Lyonia ovalifolia*	Ericaceae	Tree
62	*Magonila campbellii*	Magnoliaceae	Tree
63	*Michelia doltsopa*	Magnoliaceae	Tree

64	*Mimulus nepalensis*	Scrophulariaceae	Herb
65	*Myrsine semiserrata*	Myrsinaceae	Tree
66	*Neillia rubiflora*	Rosaceae	Shrub
67	*Nepeta lamiopsis*	Labiatae	Herb
68	*Oberonia* sp.	Orchidaceae	Orchid
69	*Oleandra pistillaris*	Olendraceae	Fern
70	*Parochetus communis*	Leguminosae	Herb
71	*Parthenocissus semicordata*	Vitaceae	Climber
72	*Peperomia tetraphylla*	Piperaceae	Herb
73	*Persicaria* sp.	Polygonaceae	Herb
74	*Philadelphus tomentosus*	Philadelphaceae	Shrub
75	*Photinia integrifolia*	Rosaceae	Shrub/Tree
76	*Plantago erosa*	Plantaginaceae	Herb
77	*Prunus cerasoides*	Rosaceae	Shrub/Tree
78	*Pseudognaphalium affine*	Compositae	Herb
79	*Pteridium* sp.	Dennataedtiaceae	Fern
80	*Pteris* sp.	Polypodiaceae	Tree
81	*Pueraria peduncularis*	Leguminosae	Herb
82	*Pyrossia boothii*	Pyrolaceae	Fern
83	*Quercus glauca*	Fagaceae	Tree
84	*Quercus griffithii*	Fagaceae	Tree
85	*Quercus lamellosa*	Fagaceae	Tree
86	*Quercus oxyodon*	Fagaceae	Tree
87	*Rhododendron arboreum*	Ericaceae	Tree
88	*Rhododendron dalhousiae*	Ericaceae	Shrub
89	*Rhododendron edgeworthii*	Ericaceae	Shrub
90	*Rhododendron griffithianum*	Ericaceae	Shrub/Tree
91	*Rhododendron lindleyi*	Ericaceae	Shrub
92	*Rhus chinensis*	Anacardiaceae	Tree
93	*Rhus hookeri*	Anacardiaceae	Shrub/Tree
94	*Ribes* sp.	Grossulariaceae	Shrub
95	*Rubia manjith*	Rubiaceae	Climber
96	*Rubus biflorus*	Rosaceae	Shrub
97	*Rubus ellipticus*	Rosaceae	Shrub
98	*Rubus paniculatus*	Rosaceae	Climber
99	*Rubus* sp.	Rosaceae	Shrub
100	*Rumex nepalensis*	Polygonaceae	Herb
101	*Schoenoplectus sp*	Cyperaceae	Herb
102	*Scurrula elata*	Loranthaceae	Shrub

103	*Senecio scandens*	Compositae	Herb
104	*Smilax* sp.	Smilacaceae	Shrub
105	*Sorbus griffithii*	Rosaceae	Tree
106	*Sorbus* sp.	Rosaceae	Tree
107	*Strobilanthes* sp.	Acanthaceae	Shrub
108	*Symplocos dryophila*	Symplocaceae	Tree
109	*Symplocos glomerata*	Symplocaceae	Tree
110	*Symplocos lucida*	Symplocaceae	Tree
111	*Symplocos ramosissima*	Symplocaceae	Shrub/Tree
112	*Symplocos* sp.	Symplocaceae	Tree
113	*Tupistra* sp.	Convallariaceae	Herb
114	*Vaccinium* sp.	Ericaceae	Shrub
115	*Vandopsis undulata*	Orchidaceae	Orchid
116	*Viburnum cylindricum*	Caprifoliaceae	Shrub
117	*Viscum* sp.	Loranthaceae	Shrub
118	*Vitis* sp.	Vitaceae	Climber
119	*Zanthoxylum* sp.	Rutaceae	Shrub

Annex 1.4: List of plant species recorded from Adit-3

Adit 3			
Sl.No	**Scientific Name**	**Family**	**Habit**
1	*Acer campbellii*	Aceraceae	Tree
2	*Acer* sp.	Aceraceae	Tree
3	*Achyranthes bidentata*	Amaranthaceae	Herb
4	*Aconogonon campanulatum*	Polygonaceae	Herb
5	*Aconogonon molle*	Polygonaceae	Herb
6	*Actinidia callosa*	Actinidiaceae	Shrub
7	*Agapetes incurvata*	Ericaceae	Shrub
8	*Agapetes serpens*	Ericaceae	Shrub
9	*Ageratina adenophora*	Compositae	Herb
10	*Agrimonia pilosa*	Rosaceae	Herb
11	*Agrostophyllum callosum*	Orchidaceae	Orchid
12	*Ainsliaea aptera*	Compositae	Herb
13	*Alnus nepalensis*	Betulaceae	Tree
14	*Anaphalis* sp.	Compositae	Herb
15	*Anoectochilus* sp.	Orchidaceae	Orchid
16	*Anthogonium gracile*	Orchidaceae	Orchid
17	*Arisaema* sp. 1	Araceae	Herb

18	*Aristolochia griffithii*	Aristolochiaceae	Woody Climber
19	*Artemisia vulgaris*	Compositae	Herb
20	*Bamboo* sp.	Gramineae	Bamboo
21	*Begonia sp.*	Begoniaceae	Herb
22	*Berberis asiatica*	Berberidaceae	Shrub
23	*Berberis* sp.	Berberidaceae	Shrub
24	*Betula alnoides*	Betulaceae	Tree
25	*Bidens pilosa*	Compositae	Herb
26	*Boehemeria* sp.	Urticaceae	Herb
27	*Brassaiopsis mitis*	Araliaceae	Tree
28	*Breynia retusa*	Euphorbiaceae	Shrub
29	*Buddleja asiatica*	Buddlejaceae	Shrub
30	*Buddleja* sp.	Buddlejaceae	Shrub
31	*Bulbophyllum guttlatum*	Orchidaceae	Orchid
32	*Bulbophyllum reptans*	Orchidaceae	Orchid
33	*Bulbophyllum* sp. 1	Orchidaceae	Orchid
34	*Carex* sp.	Cyperaceae	Grass
35	*Casearia glomerata*	Flacourtiaceae	Shrub/Tree
36	*Castanopsis tribuloides*	Fagaceae	Tree
37	*Cautleya gracilis*	Zingiberaceae	Herb
38	*Cinnanamoum* sp.	Lauraceae	Shrub/Tree
39	*Coelogyne nitida*	Orchidaceae	Orchid
40	*Coelogyne schultesii*	Orchidaceae	Orchid
41	*Commelina* sp.	Commelinaceae	Herb
42	*Conyza* sp.	Compositae	Herb
43	*Cotoneaster microphyllus*	Rosaceae	Shrub
44	*Crassocephalum crepidoides*	Compositae	Herb
45	*Cryptochilus lutea*	Orchidaceae	Orchid
46	*Cymbidium* sp.	Orchidaceae	Orchid
47	*Cynoglossum furcatum*	Boraginaceae	Herb
48	*Cyperus* sp.	Cyperaceae	Grass
49	*Daphne bholua*	Thymelaeaceae	Shrub
50	*Dendrobium falconari*	Orchidaceae	Orchid
51	*Dendrobium hookerianum*	Orchidaceae	Orchid
52	*Dendrobium longicornu*	Orchidaceae	Orchid
53	*Dendrobium* sp.	Orchidaceae	Orchid
54	*Desmodium* sp.	Leguminosae	Shrub
55	*Dichrocephala integrifolia*	Compositae	Herb

56	*Docynia indica*	Rosaceae	Tree
57	*Drynaria propinqua*	Polypodiaceae	Fern
58	*Edgeworthia gardeneri*	Cucurbitaceae	Shrub
59	*Elaeagnus parvifolia*	Elaeagnaceae	Shrub
60	*Elsholtzia fruticosa*	Labiatae	Shrub
61	*Epigenium fusuces*	Orchidaceae	Orchid
62	*Epigenium* sp.	Orchidaceae	Orchid
63	*Eria coronaria*	Orchidaceae	Orchid
64	*Eria* sp.	Orchidaceae	Orchid
65	*Erythrina stricta*	Leguminosae	Tree
66	*Eupatorium marei*	Compositae	Herb
67	*Eurya acuminata*	Theaceae	Shrub/Tree
68	*Fagopyrum dibotrys*	Polygonaceae	Herb
69	*Galinsoga parviflora*	Compositae	Herb
70	*Galium aparine*	Rubiaceae	Herb
71	*Gaultheria fragrantissima*	Ericaceae	Shrub
72	*Gaultheria hookeri*	Ericaceae	Shrub
73	*Gaultheria nummularioides*	Ericaceae	Shrub
74	*Gaultheria semi-infera*	Ericaceae	Shrub
75	*Geranium nepalense*	Geraniaceae	Herb
76	*Gleichenia gigantea*	Gleicheniaceae	Fern
77	*Goodyera sp.*	Orchidaceae	Orchid
78	*Hedera nepalensis*	Araliaceae	Woody Climber
79	*Hedera* sp.	Araliaceae	Shrub
80	*Hedychium aurantiacum*	Zingiberaceae	Herb
81	*Hedychium* sp.	Zingiberaceae	Herb
82	*Hemiphragma heterophyllum*	Scrophulariaceae	Herb
83	*Holboellia latifolia*	Lardizabalaceae	Shrub
84	*Hypericum* sp.	Hypericaceae	Herb
85	*Hypoxis aurea*	Hypoxidaceae	Herb
86	*Ilex dipyrena*	Aquifoliaceae	Tree
87	*Indigofera dosua*	Leguminosae	Shrub
88	*Indigofera* sp.	Leguminosae	Shrub
89	*Inula cappa*	Cucurbitaceae	Herb
90	*Ione bicolor*	Orchidaceae	Orchid
91	*Ione cirrhata*	Orchidaceae	Orchid
92	*Ione* sp.	Orchidaceae	Orchid
93	*Kydia* sp.	Malvaceae	Tree

94	*Leucas ciliata*	Labiatae	Herb
95	*Ligustrum confortum*	Oleaceae	Shrub
96	*Lithocarpus* sp.	Fagaceae	Tree
97	*Lyonia ovalifolia*	Ericaceae	Tree
98	*Michelia doltsopa*	Magnoliaceae	Tree
99	*Myrsine semiserrata*	Myrsinaceae	Shrub
100	*Nayariophyton zizyphifolium*	Malvaceae	Shrub/Tree
101	*Nephrolepsis cordifolia*	Nephrolepidaceae	Fern
102	*Oberonia* sp.	Orchidaceae	Orchid
103	*Otochilus lancilabius*	Orchidaceae	Orchid
104	*Parthenocissus semicordata*	Vitaceae	Climber
105	*Pentapanax* sp.	Araliaceae	Shrub/Tree
106	*Peperomia tetraphylla*	Piperaceae	Herb
107	*Persicaria nepalensis*	Polygonaceae	Herb
108	*Pinus roxburghii*	Pinaceae	Tree
109	*Pinus wallichiana*	Pinaceae	Tree
110	*Phyllanthus* sp.	Euphorbiaceae	Shrub
111	*Phytolacca acinosa*	Phytolaccaceae	Herb
112	*Plantago erosa*	Plantaginaceae	Herb
113	*Pleione praecox*	Orchidaceae	Orchid
114	*Potentilla* sp.	Rosaceae	Herb
115	*Pouzolzia* sp.	Urticaceae	Herb
116	*Pseudognaphalium affine*	Compositae	Herb
117	*Pteridium aquilium*	Dennataedtiaceae	Fern
118	*Pteris* sp.	Polypodiaceae	Fern
119	*Pyrossia boothii*	Pyrolaceae	Fern
120	*Quercus glauca*	Fagaceae	Tree
121	*Quercus griffithii*	Fagaceae	Tree
122	*Quercus lamellosa*	Fagaceae	Tree
123	*Quercus lanata*	Fagaceae	Tree
124	*Rhododendron arboreum*	Ericaceae	Tree
125	*Rhododendron edgeworthii*	Ericaceae	Shrub
126	*Rhododendron falconeri*	Ericaceae	Shrub/Tree
127	*Rhododendron lindleyi*	Ericaceae	Shrub
128	*Rhus chinensis*	Anacardiaceae	Tree
129	*Rhus hookeri*	Anacardiaceae	Tree
130	*Rhus* sp.	Anacardiaceae	Tree
131	*Rubia manjith*	Rubiaceae	Climber
132	*Rubus ellipticus*	Rosaceae	Shrub

133	*Rubus paniculatus*	Rosaceae	Climber
134	*Rubus* sp.	Rosaceae	Shrub
135	*Rumex nepalensis*	Polygonaceae	Herb
136	*Schima wallichii*	Theaceae	Tree
137	*Scurrula elata*	Loranthaceae	Shrub
138	*Scutellaria discolor*	Labiatae	Herb
139	*Senecio scandens*	Compositae	Herb
140	*Sigesbeckia orientalis*	Compositae	Herb
141	*Smilax* sp.	Smilacaceae	Shrub
142	*Solanum nigrum*	Solanaceae	Herb
143	*Strobilanthes* sp.	Acanthaceae	Shrub
144	*Swertia* sp.	Gentianaceae	Herb
145	*Symplocos glomerata*	Symplocaceae	Tree
146	*Symplocos ramosissima*	Symplocaceae	Shrub/Tree
147	*Symplocos sumuntia*	Symplocaceae	Tree
148	*Tetrastigma* sp.	Vitaceae	Climber
149	*Thladiantha cordifolia*	Cucurbitaceae	Climber
150	*Vaccinium* sp.	Ericaceae	Shrub
151	*Vaccinium vacciniaceum*	Ericaceae	Shrub
152	*Vaccinium retusa*	Ericaceae	Shrub
153	*Vandopsis undulata*	Orchidaceae	Orchid
154	*Viburnum cylindricum*	Caprifoliaceae	Shrub
155	*Vitis* sp.	Vitaceae	Climber

Annex 1.5: List of plant species recorded from Adit-4

Adit IV			
SI.No	**Scientific Name**	**Family**	**Habit**
1	*Acer campbellii*	Aceraceae	Tree
2	*Aconogonon molle*	Polygonaceae	Herb
3	*Actinidia callosa*	Actinidiaceae	Shrub
4	*Agapetes serpens*	Ericaceae	Shrub
5	*Ageratina adenophora*	Compositae	Herb
6	*Alnus nepalensis*	Betulaceae	Tree
7	*Anaphalis* sp.	Compositae	Herb
8	*Arisaema* sp.	Araceae	Herb
9	*Artemisia vulgaris*	Compositae	Herb
10	*Asplenium* sp.	Malpighiaceae	Herb
11	*Berberis* sp.	Berberidaceae	Shrub

12	*Betula alnoides*	Betulaceae	Tree
13	*Bidens pilosa*	Compositae	Herb
14	*Boehemeria* sp.	Urticaceae	Herb
15	*Buddleja* sp.	Buddlejaceae	Shrub
16	*Carpinus viminea*	Betulaceae	Tree
17	*Crassocephalum crepidoides*	Compositae	Herb
18	*Castanopsis tribuloides*	Fagaceae	Tree
19	*Castanopsis hystrix*	Fagaceae	Tree
20	*Cautleya gracilis*	Zingiberaceae	Herb
21	*Centella asiatica*	Umbelliferae	Herb
22	*Cryptomeria japonica*	Taxodiaceae	Tree
23	*Conyza* sp.	Compositae	Herb
24	*Cynoglossum furcatum*	Boraginaceae	Herb
25	*Cynoglossum lanceolatum*	Boraginaceae	Herb
26	*Daphne bholua*	Thymelaeaceae	Shrub
27	*Desmodium* sp.	Leguminosae	Herb
28	*Dichrocephala integrifolia*	Compositae	Herb
29	*Edgeworthia gardeneri*	Thymelaeaceae	Shrub
30	*Elaeagnus pyriformis*	Elaeagnaceae	Shrub
31	*Elsholtzia* sp.	Labiatae	Herb
32	*Equisetum* sp.	Gesneriaceae	Herb
33	*Eurya acuminata*	Theaceae	Shrub/Tree
34	*Ficus* sp.	Moraceae	Climber
35	*Gaultheria fragratissima*	Ericaceae	Shrub
36	*Gleichenia gigantea*	Gleicheniaceae	Fern
37	*Hackelia* sp.	Boraginaceae	Herb
38	*Hedera nepalensis*	Araliaceae	Woody Climber
39	*Hedychium aurantiacum*	Zingiberaceae	Herb
40	*Hypericum* sp.	Hypericaceae	Shrub
41	*Indigofera dosua*	Leguminosae	Shrub
42	*Leucas ciliata*	Labiatae	Herb
43	*Lobelia* sp.	Campanulaceae	Shrub
44	*Lyonia ovalifolia*	Ericaceae	Tree
45	*Oleandra pistillaris*	Olendraceae	Fern
46	*Oxalis corniculata*	Oxalidaceae	Herb
47	*Peperomia tetraphylla*	Piperaceae	Herb
48	*Persea duthiei*	Lauraceae	Tree
49	*Persicaria nepalensis*	Polygonaceae	Herb
50	*Persicaria runcinata*	Polygonaceae	Herb

51	*Pilea* sp.	Urticaceae	Herb
52	*Plantago erosa*	Plantaginaceae	Herb
53	*Pseudognaphalium affine*	Compositae	Herb
54	*Pyrossia boothii*	Pyrolaceae	Fern
55	*Quercus grifithii*	Fagaceae	Tree
56	*Quercus lamellosa*	Fagaceae	Tree
57	*Quercus lanata*	Fagaceae	Tree
58	*Rhododendron arboreum*	Ericaceae	Tree
59	*Rhus chinensis*	Anacardiaceae	Tree
60	*Rhus* sp.	Anacardiaceae	Tree
61	*Ribes* sp.	Grossulariaceae	Shrub
62	*Rubus biflorus*	Rosaceae	Shrub
63	*Rubus ellipticus*	Rosaceae	Shrub
64	*Rubus paniculatus*	Rosaceae	Climber
65	*Saurauja nepaulensis*	Actinidiaceae	Tree
66	*Scurrula elata*	Loranthaceae	Shrub
67	*Senecio scandens*	Compositae	Herb
68	*Smilax* sp.	Smilacaceae	Shrub
69	*Sorbus griffithii*	Rosaceae	Tree
70	*Strobilanthes* sp.	Acanthaceae	Shrub
71	*Tetradium* sp.	Rutaceae	Tree
72	*Thalictrum* sp.	Ranunculaceae	Shrub
73	*Vaccinium vacciniaceum*	Ericaceae	Shrub
74	*Viburnum cylindricum*	Caprifoliaceae	Shrub/Tree
75	*Viburnum erubescens*	Caprifoliaceae	Shrub
76	*Viburnum* sp.	Caprifoliaceae	Shrub
77	*Viscum* sp.	Loranthaceae	Shrub
78	*Wendlandia coriaceae*	Compositae	Shrub/Tree
79	*Woodwardia unigemmata*	Lythraceae	Fern

Annex 1.6: List of species recorded from Adit-5

Adit V			
SI.No	**Scientific Name**	**Family**	**Habit**
1	*Aconogonon campanulatum*	Polygonaceae	Herb
2	*Aconogonon molle*	Polygonaceae	Herb
3	*Agapetes incurvata*	Ericaceae	Shrub
4	*Agapetes serpens*	Ericaceae	Shrub
5	*Agapetes* sp.	Ericaceae	Shrub

6	*Ageratina adenophora*	Compositae	Herb
7	*Agrimonia pilosa*	Rosaceae	Herb
8	*Alnus nepalensis*	Betulaceae	Tree
9	*Anaphalis* sp.	Compositae	Herb
10	*Arisaema consanguineum*	Araceae	Herb
11	*Arisaema* sp. 2	Araceae	Herb
12	*Artemisia vulgaris*	Compositae	Herb
13	*Bamboo*	Gramineae	Bamboo
14	*Berberis asiatica*	Berberidaceae	Shrub
15	*Brassaiopsis mitis*	Araliaceae	Tree
16	*Cannabis sativa*	Cannabceae	Herb
17	*Carassocephalum crepidoides*	Compositae	Herb
18	*Carex* sp. 1	Cyperaceae	Grass
19	*Carpinus viminea*	Betulaceae	Tree
20	*Chenopodium ambrosioides*	Chenopodiaceae	Herb
21	*Cirsium* sp.	Compositae	Herb
22	*Clematis connata*	Ranunculaceae	Climber
23	*Codonopsis* sp.	Campanulaceae	Climber
24	*Commelina* sp.	Commelinaceae	Herb
25	*Conyza* sp.	Compositae	Herb
26	*Cyperus cyperoides*	Cyperaceae	Grass
27	*Debregeasia* sp.	Urticaceae	Tree
28	*Desmodium* sp.	Leguminosae	Herb
29	*Dichrocephala integrifolia*	Compositae	Herb
30	*Dipsacus inermis*	Dipsacaceae	Herb
31	*Docynia indica*	Rosaceae	Tree
32	*Drymaria cordata*	Caryophyllaceae	Herb
33	*Drynaria propinqua*	Polypodiaceae	Fern
34	*Elaeagnus pyriformis*	Elaeagnaceae	Shrub
35	*Elsholtzia fruticosa*	Labiatae	Shrub
36	*Erythrina arboresence*	Leguminosae	Tree
37	*Eurya acuminata*	Theaceae	Shrub/Tree
38	*Eurya* sp.	Theaceae	Shrub/Tree
39	*Fagopyrum dibotrys*	Polygonaceae	Herb
40	*Fragaria nubicola*	Rosaceae	Herb
41	*Galinsoga ciliata*	Compositae	Herb
42	*Galium aparine*	Rubiaceae	Herb
43	*Gaultheria fragrantissima*	Ericaceae	Shrub
44	*Geranium nepalense*	Geraniaceae	Herb

45	*Hedychium aurantiacum*	Zingiberaceae	Herb
46	*Houttuynia cordata*	Saururaceae	Herb
47	*Hydrocotyle himalaica*	Umbelliferae	Herb
48	*Hypericum* sp.	Hypericaceae	Shrub
49	*Impatiens* sp.	Balsaminaceae	Herb
50	*Indigofera dosua*	Leguminosae	Shrub
51	*Juglans regia*	Juglandaceae	Tree
52	*Juncus* sp.	Juncaceae	Herb
53	*Leucas ciliata*	Labiatae	Herb
54	*Leycesteria formosa*	Caprifoliaceae	Shrub
55	*Litsea* sp.	Lauraceae	Tree
56	*Lycopodium sp*	Lycopodiaceae	Fern
57	*Lyonia ovalifolia*	Ericaceae	Tree
58	*Mimulus nepalensis*	Scrophulariaceae	Herb
59	*Neillia rubiflora*	Rosaceae	Shrub
60	*Oxalis corniculata*	Oxalidaceae	Herb
61	*Parochetus communis*	Leguminosae	Herb
62	*Persicaria nepalensis*	Polygonaceae	Herb
63	*Pilea* sp.	Urticaceae	Herb
64	*Pinus bhutanica*	Pinaceae	Tree
65	*Plantago erosa*	Plantaginaceae	Herb
66	*Potentilla* sp.	Rosaceae	Herb
67	*Pouzolzia* sp.	Urticaceae	Herb
68	*Primula denticulata*	Primulaceae	Herb
69	*Pseudognaphalium affine*	Compositae	Herb
70	*Pteridium aquilium*	Dennataedtiaceae	Fern
71	*Pueraria peduncularis*	Leguminosae	Herb
72	*Quercus griffithii*	Fagaceae	Tree
73	*Quercus lanata*	Fagaceae	Tree
74	*Ranunculus* sp.	Ranunculaceae	Herb
75	*Rhododendron arboreum*	Ericaceae	Tree
76	*Rhus Chinensis*	Anacardiaceae	Tree
77	*Rosa brunonii*	Rosaceae	Climber
78	*Rubia manjith*	Rubiaceae	Climber
79	*Rubus biflorus*	Rosaceae	Shrub
80	*Rubus ellipticus*	Rosaceae	Shrub
81	*Rumex nepalensis*	Polygonaceae	Herb
82	*Salix* sp.	Salicaceae	Tree
83	*Scurrula elata*	Loranthaceae	Shrub

84	*Senecio laetus*	Compositae	Herb
85	*Sigesbeckia orientalis*	Compositae	Herb
86	*Solanum viarum*	Solanaceae	Herb
87	*Solena amplexicaulis*	Cucurbitaceae	Climber
88	*Sonchus* sp.	Compositae	Herb
89	*Strobilanthes* sp.	Acanthaceae	Shrub
90	*Swertia* sp.	Gentianaceae	Herb
91	*Tetrastigma* sp.	Vitaceae	Climber
92	*Thladiantha cordifolia*	Cucurbitaceae	Climber
93	*Trifolium repens*	Leguminosae	Herb
94	*Vaccinium vacciniaceum*	Ericaceae	Shrub
95	*Verbascum thapsus*	Scrophulariaceae	Herb
96	*Viburnum cylindricum*	Caprifoliaceae	Shrub/Tree
97	*Viburnum erubescens*	Caprifoliaceae	Shrub
98	*Viola* sp.	Violaceae	Herb
99	*Viscum album*	Loranthaceae	Shrub
100	*Xanthium indicum*	Compositae	Herb
101	*Yushania* sp.	Gramineae	Bamboo
102	*Zanthoxyllum* sp.	Rutaceae	Shrub/Tree

Annex 1.7: List of floral species recorded from Surge Shaft

Surge Plant			
SI.No	**Scientific Name**	**Family**	**Habit**
1	*Acer campbellii*	Aceraceae	Tree
2	*Acer cappadocicum*	Aceraceae	Tree
3	*Achyranthes bidentata*	Amaranthaceae	Herb
4	*Aconogonon molle*	Polygonaceae	Herb
5	*Actinidia callosa*	Actinidiaceae	Shrub
6	*Agapetes incurvata*	Ericaceae	Shurb
7	*Agapetes serpens*	Ericaceae	Shrub
8	*Ageratina adenophora*	Compositae	Herb
9	*Agrostophyllum callosum*	Orchidaceae	Orchid
10	*Ainsliaea aptera*	Compositae	Herb
11	*Albizia sherriffii*	Leguminosae	Tree
12	*Alnus nepalensis*	Betulaceae	Tree
13	*Anaphalis* sp.	Compositae	Tree
14	*Anthogonium gracile*	Orchidaceae	Orchid
15	*Ardisia macrophylla*	Myrsinaceae	Shrub

16	*Aristolochia griffithii*	Aristolochiaceae	Wood Climber
17	*Artemisia vulgaris*	Compositae	Herb
18	*Asplenium* sp.	Malpighiaceae	Fern
19	*Asyneuma fulgens*	Campanulaceae	Herb
20	*Begonia* sp.	Begoniaceae	Herb
21	*Berberis aristata*	Berberidaceae	Shrub
22	*Berberis asiatica*	Berberidaceae	Shrub
23	*Betula alnoides*	Betulaceae	Tree
24	*Betula utilis*	Betulaceae	Tree
25	*Bidens pilosa*	Compositae	Herb
26	*Boehemeria* sp.	Urticaceae	Herb
27	*Brassaiopsis mitis*	Araliaceae	Tree
28	*Buddleja asiatica*	Buddlejaceae	Shrub
29	*Bulbophyllum reptans*	Orchidaceae	Orchid
30	*Bulbophyllum* sp.	Orchidaceae	Orchid
31	*Carex* sp.	Cyperaceae	Grass
32	*Carpinus viminea*	Betulaceae	Tree
33	*Castanopsis hystrix*	Fagaceae	Tree
34	*Cautleya gracilis*	Zingiberaceae	Herb
35	*Centella asiatica*	Umbelliferae	Herb
36	*Ceropegia* sp	Asclepiadaceae	Climber
37	*Ceropegia dorjii*	Asclepiadaceae	Climber
38	*Chelianthes* sp.	Pteridaceae	Fern
39	*Cirsium* sp.	Compositae	Herb
40	*Clematis* sp.	Ranunculaceae	Climber
41	*Coelogyne* sp.	Orchidaceae	Orchid
42	*Commelina* sp.	Commelinaceae	Herb
43	*Corydalis leptocarpa*	Fumariaceae	Herb
44	*Crassocephalum crepidoides*	Compositae	Herb
45	*Crotalaria* sp.	Fabaceae	Herb
46	*Croton* sp.	Euphorbiaceae	Shurb
47	*Cupressus corneyana*	Cupressaceae	Tree(Plantation)
48	*Cynoglossum furcatum*	Boraginaceae	Herb
49	*Daphne bholua*	Thymelaeaceae	Shrub
50	*Dendrobium hookerianum*	Orchidaceae	Orchid
51	*Dendrobium longicornu*	Orchidaceae	Orchid
52	*Desmodium elagans*	Leguminosae	Shrub

53	*Dichrocephala intergrifolia*	Compositae	Herb
54	*Docynia indica*	Rosaceae	Tree
55	*Drynaria propinqua*	Polypodiaceae	Fern
56	*Dryopteris* sp.	Caryophyllaceae	Fern
57	*Ehretia* sp.	Boraginaceae	Tree
58	*Elaeocarpus lanceifolius*	Elaeocarpaceae	Tree
59	*Elsholtzia fruticosa*	Labiatae	Shrub
60	*Epigenium* sp.	Orchidaceae	Orchid
61	*Equisetum* sp.	Gesneriaceae	Herb
62	*Eria coronaria*	Orchidaceae	Orchid
63	*Eria* sp.	Orchidaceae	Orchid
64	*Eria spicata*	Orchidaceae	Orchid
65	*Erytherina stricta*	Leguminosae	Tree
66	*Eupatorium marei*	Compositae	Herb
67	*Eurya acuminata*	Theaceae	Shrub/Tree
68	*Eurya serreta*	Theaceae	Shrub/Tree
69	*Exbucklandia populnea*	Hamamelidaceae	Tree
70	*Fagopyrum dibotrys*	Polygonaceae	Herb
71	*Galium aparine*	Rubiaceae	Herb
72	*Gastrochilus* sp.	Orchidaceae	Orchid
73	*Gaultheria fragrantissima*	Ericaceae	Shrub
74	*Gentiana* sp.	Gentianaceae	Herb
75	*Geranium* sp.	Geraniaceae	Herb
76	*Gynura* sp.	Compositae	Herb
77	*Hedera nepalensis*	Araliaceae	Wood Climber
78	*Hedychium aurantiacum*	Zingiberaceae	Herb
79	*Hedychium* sp.	Zingiberaceae	Herb
80	*Hedychium spicatum*	Zingiberaceae	Herb
81	*Holboellia latifolia*	Lardizabalaceae	Shrub
82	*Houttuynia cordata*	Saururaceae	Herb
83	*Hypericum* sp.	Hypericaceae	Shurb
84	*Ilex dipyrena*	Aquifoliaceae	Tree
85	*Impatiens* sp.	Balsaminaceae	Herb
86	*Indigofera dosua*	Leguminosae	Shrub
87	*Inula cappa*	Leguminosae	Herb
88	*Juglans regia*	Juglandaceae	Tree
89	*Leucas ciliata*	Labiatae	Herb
90	*Lycopodium calvatum*	Lycopodiaceae	Fern

91	*Lyonia ovalifolia*	Ericaceae	Tree
92	*Macarange* sp.	Euphorbiaceae	Tree
93	*Michelia doltsopa*	Magnoliaceae	Tree
94	*Myrsine semiserrata*	Myrsinaceae	Shrub/Tree
95	*Neillia rubiflora*	Rosaceae	Shrub
96	*Neolitsea foliosa*	Lauraceae	Tree
97	*Nepeta lamiopsis*	Labiatae	Herb
98	*Nephrolepis cordifolia*	Nephrolepidaceae	Fern
99	*Oberonia falcata*	Orchidaceae	Orchid
100	*Oberonia* sp.	Orchidaceae	Orchid
101	*Oleandra pistillaris*	Olendraceae	Fern
102	*Ophiopogon* sp.	Convallariaceae	Grass
103	*Otochilus* sp.	Orchidaceae	Orchid
104	*Parthenocissus semicordata*	Vitaceae	Climber
105	*Peperomia tetraphylla*	Piperaceae	Herb
106	*Persea clarkeana*	Lauraceae	Tree
107	*Persea* sp.	Lauraceae	Tree
108	*Persicaria capitata*	Polygonaceae	Herb
109	*Persicaria* sp.	Polygonaceae	Herb
110	*Phalaenopsis taenialis*	Orchidaceae	Orchid
111	*Phytolacca acinosa*	Phytolaccaceae	Shrub
112	*Pilea* sp.	Urticaceae	Herb
113	*Plagiogyria* sp.	Plagiogyriaceae	Fern
114	*Plantago erosa*	Plantaginaceae	Herb
115	*Pleione praecox*	Orchidaceae	Orchid
116	*Polygala arillata*	Polygalaceae	Shrub
117	*Polystichum nepalense*	Dryopteridaceae	Fern
118	*Prinsepia utilis*	Rosaceae	Shurb
119	*Prunus cerasoides*	Rosaceae	Tree
120	*Pseudognaphalium affine*	Compositae	Herb
121	*Pteridium* sp.	Dennataedtiaceae	Fern
122	*Pteris* sp.	Polypodiaceae	Fern
123	*Pyrossia boothii*	Pyrolaceae	Fern
124	*Pyrrosia boothii*	Pyrolaceae	Fern
125	*Pyrrosia* sp.	Pyrolaceae	Fern
126	*Quercus griffithii*	Fagaceae	Tree
127	*Quercus lamellosa*	Fagaceae	Tree
128	*Quercus lanata*	Fagaceae	Tree

129	*Quercus oxyodon*	Fagaceae	Tree
130	*Rhododendron arboreum*	Ericaceae	Tree
131	*Rhus chinensis*	Anacardiaceae	Tree
132	*Rhus chinensis*	Anacardiaceae	Tree
133	*Rhus hookeri*	Anacardiaceae	Tree
134	*Rosa brunonii*	Rosaceae	Climber
135	*Rosa macrophylla*	Rosaceae	Climber
136	*Rubia cordifolia*	Gramineae	Climber
137	*Rubus ellipticus*	Rosaceae	Shrub
138	*Rubus paniculatus*	Rosaceae	Shrub
139	*Rubus* sp.	Rosaceae	Shrub
140	*Saurauja nepaulensis*	Actinidiaceae	Tree
141	*Schima wallichii*	Theaceae	Tree
142	*Scurrula elata*	Loranthaceae	Shurb
143	*Scurrula* sp.	Loranthaceae	Shrub
144	*Sedum* sp.	Crassulaceae	Herb
145	*Senecio scandens*	Compositae	Herb
146	*Sigesbeckia orientalis*	Compositae	Herb
147	*Smilax myrtillus*	Smilacaceae	Shrub
148	*Smilax* sp.	Smilacaceae	Shrub
149	*Solanum viarum*	Solanaceae	Herb
150	*Strobilanthes* sp.	Acanthaceae	Shrub
151	*Swertia bimaculata*	Gentianaceae	Herb
152	*Symplocos dryophila*	Symplocaceae	Tree
153	*Symplocos glomerata*	Symplocaceae	Tree
154	*Symplocos ramosissima*	Symplocaceae	Shrub/Tree
155	*Symplocos* sp.	Symplocaceae	Tree
156	*Tetrastigma* sp.	Vitaceae	Climber
157	*Thalictrum* sp.	Ranunculaceae	Shurb
158	*Thladiantha cordifolia*	Cucurbitaceae	Herb
159	*Toddalia asiatica*	Rutaceae	Climber
160	*Toricellia tillifolia*	Cornaceae	Tree
161	*Urtica* sp.	Urticaceae	Herb
162	*Vandopsis undulata*	Orchidaceae	Orchid
163	*Viburnum cylindricum*	Caprifoliaceae	Shrub/Tree
164	*Viola* sp.	Violaceae	Herb
165	*Vitis* sp.	Vitaceae	Climber
166	*Youngia japonica*	Compositae	Herb
167	*Yushania* sp.	Gramineae	Bamboo

168	*Zanthoxylum* sp.	Rutaceae	Shrub

Annex 1.8: List of plant species recorded from Power house

Power house			
SI.No	**Scientific Name**	**Family**	**Habit**
1	*Acer oblongum*	Aceraceae	Tree
2	*Achyranthes bidentata*	Amaranthaceae	Herb
3	*Aconogonon campanulatum*	Polygonaceae	Herb
4	*Aconogonon molle*	Polygonaceae	Herb
5	*Aeschynanthus sikkimensis*	Gesneriaceae	Shrub
6	*Agapetes serpens*	Ericaceae	Shrub
7	*Ageratina adenophora*	Compositae	Herb
8	*Agrostophyllum callosum*	Orchidaceae	Orchid
9	*Ainsliaea aptera*	Compositae	Herb
10	*Albizia julibrissin*	Leguminosae	Tree
11	*Albizia* sp.	Leguminosae	Tree
12	*Alnus nepalensis*	Betulaceae	Tree
13	*Anaphalis* sp.	Compositae	Herb
14	*Ardisia macrophylla*	Myrsinaceae	Shrub
15	*Artemisia* sp.	Compositae	Herb
16	*Artemisia vulgaris*	Compositae	Herb
17	*Benthamidia capitata*	Cornaceae	Tree
18	*Berberis asiatica*	Berberidaceae	Shrub
19	*Berberis* sp.	Berberidaceae	Shrub
20	*Betula alnoides*	Betulaceae	Tree
21	*Bidens pilosa*	Compositae	Herb
22	*Boehemeria* sp.	Urticaceae	Herb
23	*Brassaiopsis mitis*	Araliaceae	Tree
24	*Buddleja asiatica*	Buddlejaceae	Shrub
25	*Buddleja paniculata*	Buddlejaceae	Shrub
26	*Bulbophyllum reptans*	Orchidaceae	Orchid
27	*Bulbophyllum* sp.	Orchidaceae	Orchid
28	*Calanthe* sp.	Orchidaceae	Orchid
29	*Cannabis sativa*	Cannabceae	Herb
30	*Carex* sp.	Cyperaceae	Grass
31	*Carpinus faginea*	Betulaceae	Tree
32	*Casearia glomerata*	Flacourtiaceae	Tree
33	*Cassia lechenaultiana*	Leguminosae	Herb
34	*Castanopsis hystrix*	Fagaceae	Tree

35	*Cautleya gracilis*	Zingiberaceae	Herb
36	*Celtis* sp.	Ulmaceae	Tree
37	*Centella asiatica*	Umbelliferae	Herb
38	*Chelianthes* sp.	Pteridaceae	Fern
39	*Chenopodium album*	Chenopodiaceae	Herb
40	*Chenopodium ambrosioides*	Chenopodiaceae	Herb
41	*Cirsium* sp.	Compositae	Herb
42	*Clematis* sp.	Ranunculaceae	Climber
43	*Clinopodium umbrosum*	Labiatae	Herb
44	*Colocasia* sp.	Araceae	Herb
45	*Commelina* sp.	Commelinaceae	Herb
46	*Conyza* sp.	Compositae	Herb
47	*Coriaria nepalensis*	Coriariaceae	Shrub
48	*Corydalis leptocarpa*	Fumariaceae	Herb
49	*Crassocephalum crepidoides*	Compositae	Herb
50	*Crotalaria* sp.	Fabaceae	Herb
51	*Cuscuta* sp.	Cuscutaceae	Herb
52	*Cyathea spinulosa*	Cyathaceae	Tree Fern
53	*Cymbidium* sp.	Orchidaceae	Orchid
54	*Cynoglossum furcatum*	Boraginaceae	Herb
55	*Cynoglossum lanceolatum*	Boraginaceae	Herb
56	*Cyperus cyperoides*	Cyperaceae	Grass
57	*Cyperus* sp.	Cyperaceae	Grass
58	*Datura stramonium*	Solanaceae	Herb
59	*Debregeasia longifolia*	Urticaceae	Shrub/Tree
60	*Dendrobium fimbriatum*	Orchidaceae	Orchid
61	*Dendrobium hookerianum*	Orchidaceae	Orchid
62	*Dendrobium longicornu*	Orchidaceae	Orchid
63	*Desmodium* sp.	Leguminosae	Shrub
64	*Diaplazium esculatum*	Athyriaceae	Fern
65	*Dichroa febrifuga*	Hydrangeaceae	Shrub
66	*Dichrocephala integrifolia*	Compositae	Herb
67	*Diplazium* sp.	Athyriaceae	Fern
68	*Docynia indica*	Rosaceae	Tree
69	*Drepanostachyum intermedium*	Gramineae	Bamboo
70	*Drymaria cordata*	Caryophyllaceae	Herb
71	*Drynaria propinqua*	Polypodiaceae	Fern
72	*Dryopteris* sp.	Caryophyllaceae	Fern
73	*Elaeagnus parvifolia*	Elaeagnaceae	Shrub

74	*Elsholtzia fruticosa*	Labiatae	Shrub
75	*Engelherdia spicata*	Juglandaceae	Tree
76	*Equisetum* sp.	Gesneriaceae	Herb
77	*Eria* sp.	Orchidaceae	Orchid
78	*Eriobotrya hookeriana*	Rosaceae	Tree
79	*Erythrina stricta*	Leguminosae	Tree
80	*Eurya acuminata*	Theaceae	Shrub/Tree
81	*Eurya* sp.	Theaceae	Shrub/Tree
82	*Fagopyrum dibotrys*	Polygonaceae	Herb
83	*Galinsoga parviflora*	Compositae	Herb
84	*Galium aparine*	Rubiaceae	Herb
85	*Girardinia diversifolia*	Urticaceae	Herb
86	*Glochidion* sp.	Euphorbiaceae	Tree
87	*Grewia* sp.	Tiliaceae	Tree
88	*Hackelia* sp.	Boraginaceae	Herb
89	*Hedera nepalensis*	Araliaceae	Woody Climber
90	*Hedychium* sp.	Zingiberaceae	Herb
91	*Hoya* sp.	Asclepiadaceae	Shrub
92	*Impatiens* sp.	Balsaminaceae	Herb
93	*Indigofera dosua*	Leguminosae	Shrub
94	*Jasminium grandiflorum*	Oleaceae	Shrub
95	*Juglans regia*	Juglandaceae	Tree
96	*Juncus* sp.	Juncaceae	Herb
97	*Kydia* sp.	Malvaceae	Tree
98	*Leucas ciliata*	Labiatae	Herb
99	*Lycopodium calvatum*	Lycopodicaea	Fern
100	*Lyonia ovalifolia*	Ericaceae	Tree
101	*Macaranga* sp.	Euphorbiaceae	Tree
102	*Maesa chisia*	Myrsinaceae	Shrub
103	*Mahonia napaulensis*	Magnoliaceae	Shrub
104	*Mallotus nepalensis*	Euphorbiaceae	Shrub
105	*Mazus* sp.	Scrophulariaceae	Herb
106	*Michelia doltsopa*	Magnoliaceae	Tree
107	*Michelia velutina*	Magnoliaceae	Tree
108	*Molineria* sp.	Hypoxidaceae	Herb
109	*Morus australis*	Moraceae	Tree
110	*Murraya* sp.	Rutaceae	Shrub
111	*Nephrolepis cordifolia*	Nephrolepidaceae	Fern

112	*Nicandra physalodes*	Solanaceae	Herb
113	*Oberonia* sp.	Orchidaceae	Orchid
114	*Oleandra pistillaris*	Olendraceae	Fern
115	*Otochilus lancilabius*	Orchidaceae	Orchid
116	*Oxalis corniculata*	Oxalidaceae	Herb
117	*Parthenium hysterophorus*	Compositae	Herb
118	*Parthenocissus semicordata*	Vitaceae	Climber
119	*Peperomia tetraphylla*	Piperaceae	Herb
120	*Persicaria capitata*	Polygonaceae	Herb
121	*Persicaria maculosa*	Polygonaceae	Herb
122	*Persicaria runcinata*	Polygonaceae	Herb
123	*Persicaria* sp.	Polygonaceae	Herb
124	*Phalaenopsis taenialis*	Orchidaceae	Orchid
125	*Phytolacca acinosa*	Phytolaccaceae	Shrub
126	*Pilea* sp.	Urticaceae	Herb
127	*Piper* sp.	Piperaceae	Climber
128	*Plagiogyria* sp.	Plagiogyriaceae	Fern
129	*Plantago erosa*	Plantaginaceae	Herb
130	*Polystichum nepalense*	Dryopteridaceae	Fern
131	*Pouzolzia* sp.	Urticaceae	Herb
132	*Prinsepia utilis*	Rosaceae	Shrub
133	*Prunus cerasoides*	Rosaceae	Tree
134	*Prunus persica*	Rosaceae	Tree
135	*Pseudognaphalium affine*	Compositae	Herb
136	*Pteridium aquilium*	Dennataedtiaceae	Fern
137	*Pteridium* sp.	Dennataedtiaceae	Fern
138	*Pteris* sp.	Polypodiaceae	Fern
139	*Quercus griffithii*	Fagaceae	Tree
140	*Quercus lanata*	Fagaceae	Tree
141	*Rhododendron arboreum*	Ericaceae	Tree
142	*Rhus chinensis*	Anacardiaceae	Tree
143	*Rhus hookeri*	Anacardiaceae	Tree
144	*Rhus succedanea*	Anacardiaceae	Tree
145	*Ribes* sp.	Grossulariaceae	Shrub
146	*Rosa brunonii*	Rosaceae	Climber
147	*Rosa macrophylla*	Rosaceae	Climber
148	*Rubia cordifolia*	Rubicaea	Climber
149	*Rubus biflorus*	Rosaceae	Shrub
150	*Rubus ellipticus*	Rosaceae	Shrub

151	*Saurauja nepaulensis*	Actinidiaceae	Tree
152	*Schefflera* sp.	Araliaceae	Shrub
153	*Scurrula elata*	Loranthaceae	Shrub
154	*Scurrula* sp.	Loranthaceae	Shrub
155	*Sedum* sp.	Crassulaceae	Herb
156	*Sida acuta*	Malvaceae	Shrub
157	*Sigesbeckia orientalis*	Compositae	Herb
158	*Smilax myrtillus*	Smilacaceae	Shrub
159	*Solanum nigrum*	Solanaceae	Herb
160	*Solanum* sp.	Solanaceae	Herb
161	*Solanum viarum*	Solanaceae	Herb
162	*Solena* sp.	Cucurbitaceae	Climber
163	*Sonchus* sp.	Compositae	Herb
164	*Stephania* sp.	Menispermaceae	Climber
165	*Strobilanthes* sp.	Acanthaceae	Shrub
166	*Sunipia* sp.	Orchidaceae	Orchid
167	*Tetrastigma* sp.	Datiscaceae	Climber
168	*Thalictrum* sp.	Ranunculaceae	Shrub
169	*Thladiantha cordifolia*	Cucurbitaceae	Climber
170	*Toddalia asiatica*	Rutaceae	Climber
171	*Toricellia tillifolia*	Cornaceae	Tree
172	*Trema tomentosa*	Ulmaceae	Shrub
173	*Trichosanthes* sp.	Cucurbitaceae	Climber
174	*Urena lobata*	Malvaceae	Shrub
175	*Urtica* sp	Urticaceae	Herb
176	*Vaccinium* sp.	Ericaceae	Shrub
177	*Verbascum thapsus*	Scrophulariaceae	Herb
178	*Verbena esculenta*	Scrophulariaceae	Herb
179	*Viburnum cylindricum*	Caprifoliaceae	Shrub/Tree
180	*Viola* sp.	Violaceae	Herb
181	*Viscium album*	Loranthaceae	Shrub
182	*Vitex burmensis*	Verbenaceae	Shrub
183	*Wedlandia* sp.	Compositae	Shrub/Tree
184	*Xanthium indicum*	Compositae	Herb
185	*Yushania* sp.	Gramineae	Bamboo
186	*Zanthoxylum armatum*	Rutaceae	Shrub

Annex 1.9: A SUMMARY OF FLORAL DIVERSITY OF TANGSIBJI HYDROPOWER PROJECT SITES

S/N	Scientific name	Family	Habit
1	**TREES (ANGIOSPERMS)**		
2	*Acer campbellii*	Aceraceae	Tree
3	*Acer cappadocicum*	Aceraceae	Tree
4	*Acer oblongum*	Aceraceae	Tree
5	*Acer* sp.	Aceraceae	Tree
6	*Acer taronese*	Aceraceae	Tree
7	*Albizia julibrissin*	Leguminosae	Tree
8	*Albizia sherriffii*	Leguminosae	Tree
9	*Albizia* sp.	Leguminosae	Tree
10	*Alnus nepalensis*	Betulaceae	Tree
11	*Benthamidia capitata*	Cornaceae	Tree
12	*Betula alnoides*	Betulaceae	Tree
13	*Brassaiopsis mitis*	Araliaceae	Tree
14	*Carpinus faginea*	Betulaceae	Tree
15	*Carpinus viminea*	Betulaceae	Tree
16	*Casearia glomerata*	Flacourtiaceae	Tree
17	*Castanopsis hystrix*	Fagaceae	Tree
18	*Castanopsis tribuloides*	Fagaceae	Tree
19	*Celtis* sp.	Ulmaceae	Tree
20	*Cyathea spinulosa*	Cyathaceae	Tree Fern
21	*Daphnephyllum himalense*	Thymelaeaceae	Tree
22	*Docynia indica*	Rosaceae	Tree
23	*Ehretia* sp.	Boraginaceae	Tree
24	*Elaeocarpus lanceifolius*	Elaeocarpaceae	Tree
25	*Engelherdia spicata*	Juglandaceae	Tree
26	*Eriobotrya hookeriana*	Rosaceae	Tree
27	*Erytherina stricta*	Leguminosae	Tree
28	*Erythrina arboresence*	Leguminosae	Tree
29	*Exbucklandia populnea*	Hamamelidaceae	Tree
30	*Gamblea ciliata*	Araliaceae	Tree
31	*Glochidion* sp.	Euphorbiaceae	Tree
32	*Grewia* sp.	Tiliaceae	Tree
33	*Ilex dipyrena*	Aquifoliaceae	Tree
34	*Juglans regia*	Juglandaceae	Tree
35	*Kydia* sp.	Malvaceae	Tree
36	*Lindera pulcherrima*	Lauraceae	Tree

37	*Lindera* sp.	Lauraceae	Tree
38	*Lithocarpus* sp.	Fagaceae	Tree
39	*Litsea* sp.	Lauraceae	Tree
40	*Lyonia ovalifolia*	Ericaceae	Tree
41	*Macaranga sp.*	Euphorbiaceae	Tree
42	*Magonila campbellii*	Magnoliaceae	Tree
43	*Michelia doltsopa*	Magnoliaceae	Tree
44	*Michelia kisopa*	Magnoliaceae	Tree
45	*Michelia velutina*	Magnoliaceae	Tree
46	*Morus australis*	Moraceae	Tree
47	*Nayariophyton zizyphifolium*	Malvaceae	Tree
48	*Neolitsea foliosa*	Lauraceae	Tree
49	*Persea clarkeana*	Lauraceae	Tree
50	*Persea duthiei*	Lauraceae	Tree
51	*Persea* sp.	Lauraceae	Tree
52	*Prunus cerasoides*	Rosaceae	Tree
53	*Prunus persica*	Rosaceae	Tree
54	*Quercus glauca*	Fagaceae	Tree
55	*Quercus griffithii*	Fagaceae	Tree
56	*Quercus lamellosa*	Fagaceae	Tree
57	*Quercus lanata*	Fagaceae	Tree
58	*Quercus oxyodon*	Fagaceae	Tree
59	*Rhododendron arboreum*	Ericaceae	Tree
60	*Rhododendron kesangiae*	Ericaceae	Tree
61	*Rhus chinensis*	Anacardiaceae	Tree
62	*Rhus hookeri*	Anacardiaceae	Tree
63	*Rhus* sp.	Anacardiaceae	Tree
64	*Rhus succedanea*	Anacardiaceae	Tree
65	*Saurauja nepaulensis*	Actinidiaceae	Tree
66	*Schima wallichii*	Theaceae	Tree
67	*Sorbus griffithii*	Rosaceae	Tree
68	*Sorbus* sp.	Rosaceae	Tree
69	*Sorbus wallichii*	Rosaceae	Tree
70	*Symplocos dryophila*	Symplocaceae	Tree
71	*Symplocos glomerata*	Symplocaceae	Tree
72	*Symplocos lucida*	Symplocaceae	Tree
73	*Symplocos* sp.	Symplocaceae	Tree
74	*Symplocos sumuntia*	Symplocaceae	Tree
75	*Tetracentron sinense*	Tetracentraceae	Tree

76	*Tetradium fraxinifolium*	Rutaceae	Tree
77	*Tetradium* sp.	Rutaceae	Tree
78	*Toricellia tillifolia*	Cornaceae	Tree
79	*Zanthoxylum* sp.	Rutaceae	Tree
	CONIFER (GYMNOPSERM) TREES		
1	*Cryptomeria japonica*	Taxodiaceae	Conifer Tree
2	*Cupressus corneyana*	Cupressaceae	Conifer Tree
3	*Pinus bhutanica*	Pinaceae	Conifer Tree
4	*Pinus roxburghii*	Pinaceae	Conifer Tree
6	*Pinus wallichiana*	Pinaceae	Conifer Tree
7	*Tsuga dumosa*	Pinaceae	Conifer Tree
	TREES or SHRUBS		
1	*Alangium alpinum*	Alangiaceae	Shrub/Tree
2	*Cinnamomum* sp.	Lauraceae	Shrub/Tree
3	*Debregeasia longifolia*	Urticaceae	Shrub/Tree
4	*Debregeasia* sp.	Urticaceae	Shrub/Tree
5	*Eurya acuminata*	Theaceae	Shrub/Tree
6	*Eurya* sp.	Theaceae	Shrub/Tree
7	*Maddenia himalaica*	Rosaceae	Shrub/Tree
8	*Myrsine semiserrata*	Myrsinaceae	Shrub/Tree
9	*Pentapanax* sp.	Araliaceae	Shrub/Tree
10	*Photinia integrifolia*	Rosaceae	Shrub/Tree
11	*Rhododendron falconeri*	Ericaceae	Shrub/Tree
12	*Rhododendron grande*	Ericaceae	Shrub/Tree
14	*Rhododendron griffithianum*	Ericaceae	Shrub/Tree
15	*Rhododendron hodgsonii*	Ericaceae	Shrub/Tree
16	*Symplocos ramosissima*	Symplocaceae	Shrub/Tree
17	*Unknown* sp.		Shrub/Tree
18	*Viburnum cylindricum*	Caprifoliaceae	Shrub/Tree
19	*Wedlandia* sp.	Compositae	Shrub/Tree
20	*Wendlandia coriaceae*	Compositae	Shrub/Tree
21	*Zanthoxylum armatum*	Rutaceae	Shrub/Tree
	SHRUBS		
1	*Actinidia callosa*	Actinidiaceae	Shrub
2	*Actinidia strigosa*	Actinidiaceae	Shrub
3	*Aeschynanthus sikkimensis*	Gesneriaceae	Shrub
4	*Aeschynanthus* sp.	Gesneriaceae	Shrub
5	*Agapetes incurvata*	Ericaceae	Shurb

6	*Agapetes serpens*	Ericaceae	Shrub
7	*Agapetes* sp.	Ericaceae	Shrub
8	*Anaphalis* sp.	Compositae	Shrub
9	*Ardisia macrophylla*	Myrsinaceae	Shrub
10	*Berberis angulosa*	Berberidaceae	Shrub
11	*Berberis aristata*	Berberidaceae	Shrub
12	*Berberis asiatica*	Berberidaceae	Shrub
13	*Berberis* sp.	Berberidaceae	Shrub
14	*Breynia retusa*	Euphorbiaceae	Shrub
15	*Buddleja asiatica*	Buddlejaceae	Shrub
16	*Buddleja paniculata*	Buddlejaceae	Shrub
17	*Buddleja* sp.	Buddlejaceae	Shrub
18	*Coriaria nepalensis*	Coriariaceae	Shrub
19	*Cotoneaster microphyllus*	Rosaceae	Shrub
20	*Croton* sp.	Euphorbiaceae	Shurb
21	*Daphne bholua*	Thymelaeaceae	Shrub
22	*Dendrophthoe falcata*	Loranthaceae	Shrub
23	*Desmodium elagans*	Leguminosae	Shrub
24	*Dichroa febrifuga*	Hydrangeaceae	Shrub
25	*Edgeworthia gardeneri*	Cucurbitaceae	Shrub
26	*Elaeagnus parvifolia*	Pontederiaceae	Shrub
27	*Elsholtzia fruticosa*	Labiatae	Shrub
28	*Gaultheran fragratissima*	Ericaceae	Shrub
29	*Gaultheria hookeri*	Ericaceae	Shrub
30	*Gaultheria nummularioides*	Ericaceae	Shrub
31	*Gaultheria semi-infera*	Ericaceae	Shrub
32	*Gaultheria tricophylla*	Ericaceae	Shrub
33	*Hedera* sp.	Araliaceae	Shrub
34	*Holboellia latifolia*	Lardizabalaceae	Shrub
35	*Hoya* sp.	Asclepiadaceae	Shrub
36	*Hypercium* sp.	Hypericaceae	Shrub
37	*Indigofera dosua*	Leguminosae	Shrub
38	*Indigofera* sp.	Leguminosae	Shrub
39	*Jasminium grandiflorum*	Oleaceae	Shrub
40	*Leycesteria formosa*	Caprifoliaceae	Shrub
41	*Ligustrum confortum*	Oleaceae	Shrub
42	*Ligustrum* sp.	Oleaceae	Shrub
43	*Maesa chisia*	Myrsinaceae	Shrub
44	*Mahonia napaulensis*	Magnoliaceae	Shrub

45	*Mallotus nepalensis*	Euphorbiaceae	Shrub
46	*Murraya* sp.	Rutaceae	Shrub
47	*Neillia rubiflora*	Rosaceae	Shrub
48	*Philadelphus tomentosus*	Philadelphaceae	Shrub
49	*Phyllanthus* sp.	Euphorbiaceae	Shrub
50	*Polygala arillata*	Polygalaceae	Shrub
51	*Potentilla* sp.	Rosaceae	Shrub
52	*Rhododendron dalhousiae*	Ericaceae	Shrub
53	*Rhododendron edgeworthii*	Ericaceae	Shrub
54	*Rhododendron lindleyi*	Ericaceae	Shrub
55	*Rhododendron vaccinioides*	Ericaceae	Shrub
56	*Ribes* sp.	Grossulariaceae	Shrub
57	*Rubus biflorus*	Rosaceae	Shrub
58	*Rubus ellipticus*	Rosaceae	Shrub
59	*Rubus* sp.	Rosaceae	Shrub
60	*Sarcococca hookeriana*	Buxaceae	Shrub
61	*Schefflera* sp.	Araliaceae	Shrub
62	*Scurrula elata*	Loranthaceae	Shrub
63	*Scurrula* sp.	Loranthaceae	Shrub
64	*Sida acuta*	Malvaceae	Shrub
65	*Smilax myrtillus*	Smilacaceae	Shrub
66	*Smilax* sp.	Smilacaceae	Shrub
67	*Trema tomentosa*	Ulmaceae	Shrub
68	*Urena lobata*	Malvaceae	Shrub
69	*Vaccinium nummularia*	Ericaceae	Shrub
70	*Vaccinium retusa*	Ericaceae	Shrub
71	*Vaccinium* sp.	Ericaceae	Shrub
72	*Vaccinium vacciniaceum*	Ericaceae	Shrub
73	*Viburnum erubescens*	Caprifoliaceae	Shrub
74	*Viburnum* sp.	Caprifoliaceae	Shrub
75	*Viscium album*	Loranthaceae	Shrub
76	*Viscum* sp.	Loranthaceae	Shrub
77	*Vitex burmensis*	Verbenaceae	Shrub
78	*Zanthoxylum nepalense*	Rutaceae	Shrub
	HERBS		
1	*Achyranthes bidentata*	Amaranthaceae	Herb
2	*Aconogonon campanulatum*	Polygonaceae	Herb
3	*Aconogonon molle*	Ranunculaceae	Herb
4	*Ageratina adenophora*	Compositae	Herb

5	*Agrimonia pilosa*	Rosaceae	Herb
6	*Ainsliaea aptera*	Compositae	Herb
7	*Angelica cyclocarpa*	Umbelliferae	Herb
8	*Arisaema consanguineum*	Araceae	Herb
9	*Arisaema jacquemontii*	Araceae	Herb
10	*Arisaema* sp.	Araceae	Herb
11	*Arisaema* sp. 1	Araceae	Herb
12	*Arisaema* sp. 2	Araceae	Herb
13	*Artemisia* sp.	Compositae	Herb
14	*Artemisia vulgaris*	Compositae	Herb
15	*Astilbe rivularis*	Saxifragaceae	Herb
16	*Asyneuma fulgens*	Campanulaceae	Herb
17	*Begonia* sp.	Begoniaceae	Herb
18	*Bidens pilosa*	Compositae	Herb
19	*Boehemeria* sp.	Urticaceae	Herb
20	*Cannabis sativa*	Cannabceae	Herb
21	*Carassocephalum crepidoides*	Compositae	Herb
22	*Carpesium* sp.	Compositae	Herb
23	*Cassia lechenaultiana*	Leguminosae	Herb
24	*Cautleya gracilis*	Zingiberaceae	Herb
25	*Centella asiatica*	Umbelliferae	Herb
26	*Chenopodium album*	Chenopodiaceae	Herb
27	*Chenopodium ambrosioides*	Chenopodiaceae	Herb
28	*Chirita* sp.	Gesneriaceae	Herb
29	*Cirsium* sp.	Compositae	Herb
30	*Clinopodium umbrosum*	Labiatae	Herb
31	*Colocasia* sp.	Araceae	Herb
32	*Commelina* sp.	Commelinaceae	Herb
33	*Conyza* sp.	Compositae	Herb
34	*Corydalis leptocarpa*	Fumariaceae	Herb
35	*Crassocephalum crepidoides*	Compositae	Herb
36	*Crotalaria* sp.	Fabaceae	Herb
37	*Cuscuta* sp.	Cuscutaceae	Herb
38	*Cyanotis vaga*	Commelinaceae	Herb
39	*Cynoglossum furcatum*	Boraginaceae	Herb
40	*Cynoglossum lanceolatum*	Boraginaceae	Herb
41	*Datura stramonium*	Solanaceae	Herb
42	*Dechesnea indica*	Lardizabalaceae	Herb
43	*Desmodium* sp.	Leguminosae	Herb

44	*Dichrocephala integrifolia*	Compositae	Herb
45	*Didymocarpus* sp.	Gesneriaceae	Herb
46	*Dipsacus inermis*	Dipsacaceae	Herb
47	*Drymaria cordata*	Caryophyllaceae	Herb
48	*Duchesnea indica*	Rosaceae	Herb
49	*Elatostema* sp.	Urticaceae	Herb
50	*Elsholtzia* sp.	Labiatae	Herb
51	*Elsholtzia strobifera*	Labiatae	Herb
52	*Equisetum* sp.	Gesneriaceae	Herb
53	*Eupatorium marei*	Compositae	Herb
54	*Fagopyrum dibotrys*	Polygonaceae	Herb
55	*Fagopyrum* sp.	Polygonaceae	Herb
56	*Fragaria nubicola*	Rosaceae	Herb
57	*Galinsoga ciliata*	Compositae	Herb
58	*Galinsoga parviflora*	Compositae	Herb
59	*Gentiana capitata*	Gentianaceae	Herb
60	*Gentiana* sp.	Gentianaceae	Herb
61	*Geranium nepalense*	Geraniaceae	Herb
62	*Geranium* sp.	Geraniaceae	Herb
63	*Girardinia diversifolia*	Urticaceae	Herb
64	*Gynura* sp.	Compositae	Herb
65	*Hackelia* sp.	Boraginaceae	Herb
66	*Halenia elliptica*	Gentianaceae	Herb
67	*Hedychium aurantiacum*	Zingiberaceae	Herb
68	*Hedychium* sp.	Zingiberaceae	Herb
69	*Hedychium spicatum*	Zingiberaceae	Herb
70	*Hemiphragma heterophyllum*	Scrophulariaceae	Herb
71	*Houttuynia cordata*	Saururaceae	Herb
72	*Hydrocotyle himalaica*	Umbelliferae	Herb
73	*Hypoxis aurea*	Hypoxidaceae	Herb
74	*Impatiens* sp.	Balsaminaceae	Herb
75	*Inula cappa*	Cucurbitaceae	Herb
76	*Juncus* sp.	Juncaceae	Herb
77	*Leucas ciliata*	Labiatae	Herb
78	*Lobelia* sp.	Campanulaceae	Herb
79	*Maianthemum oleraceum*	Convallariaceae	Herb
80	*Mazus* sp.	Scrophulariaceae	Herb
81	*Mimulus nepalensis*	Scrophulariaceae	Herb
82	*Molineria* sp.	Hypoxidaceae	Herb

83	*Nepeta lamiopsis*	Labiatae	Herb
84	*Nicandra physalodes*	Solanaceae	Herb
85	*Ophiopogon* sp.	Convallariaceae	Herb
86	*Oplismenus compositus*	Gramineae	Herb
87	*Oxalis corniculata*	Oxalidaceae	Herb
88	*Panax pseudo-ginseng*	Araliaceae	Herb
89	*Parochetus communis*	Leguminosae	Herb
90	*Parthenium hysterophorus*	Compositae	Herb
91	*Peperomia tetraphylla*	Piperaceae	Herb
92	*Persicaria capitata*	Polygonaceae	Herb
93	*Persicaria maculosa*	Polygonaceae	Herb
94	*Persicaria nepalensis*	Polygonaceae	Herb
95	*Persicaria runcinata*	Polygonaceae	Herb
96	*Persicaria* sp.	Polygonaceae	Herb
97	*Persicaria* sp.1	Polygonaceae	Herb
98	*Phlomis* sp.	Labiatae	Herb
99	*Phytolacca acinosa*	Phytolaccaceae	Herb
100	*Pilea* sp.	Urticaceae	Herb
101	*Plantago erosa*	Plantaginaceae	Herb
102	*Polygonatum* sp.	Convallariaceae	Herb
103	*Pouzolzia* sp.	Urticaceae	Herb
104	*Primula* sp.	Primulaceae	Herb
105	*Primula denticulata*	Primulaceae	Herb
106	*Pseudognaphalium affine*	Compositae	Herb
107	*Pueraria peduncularis*	Leguminosae	Herb
108	*Ranunculus* sp.	Ranunculaceae	Herb
109	*Ranunculus* sp.1	Ranunculaceae	Herb
110	*Rhaphidophora* sp.	Araceae	Herb
111	*Roscoea alpina*	Zingiberaceae	Herb
112	*Rubus calycinus*	Rosaceae	Herb
113	*Rubus nepalensis*	Rosaceae	Herb
114	*Rumex nepalensis*	Polygonaceae	Herb
115	*Sambucus adnata*	Caprifoliaceae	Herb
116	*Schoenoplectus* sp.	Cyperaceae	Herb
117	*Scutellaria discolor*	Labiatae	Herb
118	*Sedum* sp.	Crassulaceae	Herb
119	*Senecio laetus*	Compositae	Herb
120	*Senecio scandens*	Compositae	Herb
121	*Sigesbeckia orientalis*	Compositae	Herb

122	*Solanum nigrum*	Solanaceae	Herb
123	*Sonchus* sp.	Compositae	Herb
124	*Sonchus* sp.	Compositae	Herb
125	*Stachys* sp.	Labiatae	Herb
126	*Stellaria vestita*	Caryophyllaceae	Herb
127	*Strobilanthes* sp.	Acanthaceae	Herb
128	*Swertia bimaculata*	Gentianaceae	Herb
129	*Swertia* sp.	Gentianaceae	Herb
130	*Synotis wallichii*	Compositae	Herb
131	*Thalictrum* sp.	Ranunculaceae	Herb
132	*Trifolium repens*	Leguminosae	Herb
133	*Tupistra nutans*	Convallariaceae	Herb
134	*Tupistra* sp.	Convallariaceae	Herb
135	*Urtica* sp	Urticaceae	Herb
136	*Valeriana* sp.	Valerianaceae	Herb
137	*Verbascum thapsus*	Scrophulariaceae	Herb
138	*Verbena esculenta*	Scrophulariaceae	Herb
139	*Viola bhutanica*	Violaceae	Herb
140	*Viola* sp.	Violaceae	Herb
141	*Xanthium indicum*	Compositae	Herb
142	*Youngia japonica*	Compositae	Herb
	ORCHIDS		
1	*Agrostophyllum callosum*	Orchidaceae	Orchid
2	*Anoectochilus* sp.	Orchidaceae	Orchid
3	*Anthogonium gracile*	Orchidaceae	Orchid
4	*Bulbophyllum guttlatum*	Orchidaceae	Orchid
5	*Bulbophyllum reptans*	Orchidaceae	Orchid
6	*Bulbophyllum* sp.	Orchidaceae	Orchid
7	*Bulbophyllum* sp. 1	Orchidaceae	Orchid
8	*Calanthe* sp.	Orchidaceae	Orchid
9	*Coelogyne nitida*	Orchidaceae	Orchid
10	*Coelogyne schultesii*	Orchidaceae	Orchid
11	*Coelogyne* sp.	Orchidaceae	Orchid
12	*Cryptochilus lutea*	Orchidaceae	Orchid
13	*Cymbidium* sp.	Orchidaceae	Orchid
14	*Dendrobium falconari*	Orchidaceae	Orchid
15	*Dendrobium fimbriatum*	Orchidaceae	Orchid
16	*Dendrobium hookerianum*	Orchidaceae	Orchid
17	*Dendrobium longicornu*	Orchidaceae	Orchid

18	*Dendrobium* sp.	Orchidaceae	Orchid
19	*Epigenium fusuces*	Orchidaceae	Orchid
20	*Eria coronaria*	Orchidaceae	Orchid
21	*Eria* sp.	Orchidaceae	Orchid
22	*Eria spicata*	Orchidaceae	Orchid
23	*Gastrochilus* sp.	Orchidaceae	Orchid
24	*Goodyera* sp.	Orchidaceae	Orchid
25	*Ione bicolor*	Orchidaceae	Orchid
26	*Ione cirrhata*	Orchidaceae	Orchid
27	*Ione* sp.	Orchidaceae	Orchid
28	*Oberonia falcata*	Orchidaceae	Orchid
29	*Oberonia* sp.	Orchidaceae	Orchid
30	*Otochilus lancilabius*	Orchidaceae	Orchid
31	*Otochilus* sp.	Orchidaceae	Orchid
32	*Phalaenopsis taenialis*	Orchidaceae	Orchid
33	*Platanthera* sp.	Orchidaceae	Orchid
34	*Pleione humulis*	Orchidaceae	Orchid
35	*Pleione praecox*	Orchidaceae	Orchid
36	*Sunipia* sp.	Orchidaceae	Orchid
37	*Vandopsis undulata*	Orchidaceae	Orchid
	FERNS		
1	*Asplenium* sp.	Malpighiaceae	Fern
2	*Chelianthes* sp.	Pteridaceae	Fern
3	*Diaplazium esculatum*	Athyriaceae	Fern
4	*Diplazium* sp.	Athyriaceae	Fern
5	*Drynaria propinqua*	Polypodiaceae	Fern
6	*Dryopteris* sp.	Caryophyllaceae	Fern
7	*Fern* sp.	Pteridaceae	Fern
8	*Gleichenia gigantea*	Gleicheniaceae	Fern
9	*Lycopodium calvatum*	Lycopodicaea	Fern
10	*Lycopodium* sp	Lycopodiaceae	Fern
11	*Nephrolepis cordifolia*	Nephrolepidaceae	Fern
12	*Oleandra pistillaris*	Olendraceae	Fern
13	*Plagiogyria* sp.	Plagiogyriaceae	Fern
14	*Polystichum nepalense*	Dryopteridaceae	Fern
15	*Pteridium aquilium*	Dennataedtiaceae	Fern
16	*Pteridium* sp.	Dennataedtiaceae	Fern
17	*Pteris* sp.	Polypodiaceae	Fern
18	*Pyrossia boothii*	Pyrolaceae	Fern

19	*Pyrrosia* sp.	Pyrolaceae	Fern
20	*Woodwardia unigemmata*	Lythraceae	Fern
	CLIMBERS		
1	*Aristolochia griffithii*	Aristolochiaceae	Woody Climber
2	*Ceropegia dorjii*	Asclepiadaceae	Climber
3	*Ceropegia* sp.	Asclepiadaceae	Climber
4	*Clematis connata*	Ranunculaceae	Climber
5	*Clematis* sp.	Ranunculaceae	Climber
6	*Clematis* sp.1	Ranunculaceae	Climber
7	*Codonopsis* sp.	Campanulaceae	Climber
8	*Ficus* sp.	Moraceae	Climber
9	*Hedera nepalensis*	Araliaceae	Woody Climber
10	*Parthenocissus semicordata*	Vitaceae	Climber
11	*Piper* sp.	Piperaceae	Climber
12	*Rosa brunonii*	Rosaceae	Climber
13	*Rosa macrophylla*	Rosaceae	Climber
14	*Rubia cordifolia*	Gramineae	Climber
15	*Rubia manjith*	Rubiaceae	Climber
16	*Rubus paniculatus*	Rosaceae	Climber
17	*Solena amplexicaulis*	Cucurbitaceae	Climber
18	*Solena* sp.	Cucurbitaceae	Climber
19	*Stephania* sp.	Menispermaceae	Climber
20	*Tetrastigma* sp.	Datiscaceae	Climber
21	*Thladiantha cordifolia*	Cucurbitaceae	Climber
22	*Toddalia asiatica*	Rutaceae	Climber
23	*Trichosanthes* sp.	Cucurbitaceae	Climber
24	*Vitis heyneana*	Vitaceae	Climber
	BAMBOOS		
1	*Bambuseae* sp.	Gramineae	Bamboo
2	Bamboo sp.	Gramineae	Bamboo
3	*Drepanostachyum intermedium*	Gramineae	Bamboo
4	*Yushania macophylla*	Gramineae	Bamboo
5	*Yushania maling*	Gramineae	Bamboo
6	*Yushania* sp.	Gramineae	Bamboo
	GRASSES		
1	*Axonopus compressus*	Gramineae	Grass
2	*Carex* sp.	Cyperaceae	Grass
3	*Carex* sp. 1	Cyperaceae	Grass
4	*Cyperus cyperoides*	Cyperaceae	Grass

5	*Cyperus* sp.	Cyperaceae	Grass
6	*Digitaria ciliaris*	Gramineae	Grass
7	*Grass* sp.	Poaceae	Grass
TOTAL SPECIES RECORDED			**421**

REFERENCES

Grieson, A.J.C & Long, D.G 1983-2000. Nomenclature of plants followed Flora of Bhutan; Vol. I Part 1, 2, 3, Vol.II Part 1, 2, 3, Vol. III Part 1, 2.

Grierson, A. J. C., & Long, D.G. (1983, 87, 91, 99, & 2001). Flora of Bhutan (vol. 1 to vol.2 part 3) *Edinburgh, U.K.: Royal Botanical Garden Edinburgh*.

Noltie, H. J. 2000. Flora of Bhutan (Vol. 3 Part 2): *Royal Botanic Garden, Edingburgh, London.*

Noss, R.F. 1990, 'Indicators for monitoring biodiversity: a hierarchical approach',*Conservation Biology,* vol. 4, no. 4, pp. 355-364.

N.R Pearce & P.J Cribb, 2002. The Orchids of Bhutan.

Polunin & Stainton., 1984, 1987, 1988.Flowers of the Himalaya, Concise flower of the Himalaya and Flowers of the Himalaya, *A supplement* (Stainton1988).

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Executive Summary

Bhutan comprises four major river systems; Dangme Chhu (Manas), Punatsang Chhu (Sunkosh), Wang Chhu (Raidak) and Amo Chhu (Toorsa) from east to west (Gurung *et al*., 2013). In addition, there are several small river basins which includes Samtse Area multi-river, Gelegphu Area multi-river, Samdrup Jongkhar Area multi-river, and Shingkhar-Lauri multi-river (BAP, 2009). Therefore, in total, 7,200 km length of river network is estimated (Petr, 1999). Moreover, NEC (2011) reported presence of 2,674 lakes in the country. Perennial flow of water in the swift flowing rivers and fair climatic condition with all rivers running north-south through steep terrains provide an ideal setting for harnessing hydropower energy. Hydropower is considered as a pillar of nation's economy.

Tangsibji Hydro Energy Limited (THyE), is located under Trongsa District, with the aim to produce 118 MW. Adding 118 MW in the production of green power energy will have a new chapter in the history of nation's economy. It will have an enormous benefit and generate good amount of income. Bhutan has estimated hydropower potential of 30,000 MW in Bhutan's Power System Master Plan (2003-22). Despite hydropower considering as jewel number one of our country, the concept of development is to have minimum negative foot print on environment. Therefore, this report comprises an environmental study along Nika Chhu through using biological indicator as a strategy for studying Nika Chhu. With the aim to create a concrete additional data base of Nika Chhu fresh water ecology, biological indicators were included as fishes, macro-invertebrates and riverine butterflies.

This report is broadly classified into three studies. The study encompasses about the fishes, macro-invertebrates and butterflies. Study investigated diversity – species composition, species abundance and diversity index. Distribution in various river habitat and the factors influencing the species distribution were also covered. Findings were reported in two different zone of stream. Lower stream zone stretches from Mangdi Chhu and Nika Chhu confluence to till Nika Chhu and Tsheringma Drup Chhu confluence. Upper stream zone covers from Dam Site of THyE to till Chuserbu confluence.

SECTION I: INTRODUCTION

Background

Bhutan is situated in the southern slope of the Eastern Himalaya, 26^{o} and 29^{o} N latitude bordered by the Tibetan autonomous region of China to its north and northwest, and by the Indian states of Sikkim, West Bengal, Assam, and Arunachal Pradesh to its southwest, south, and east (BAP, 2009). It covers an area of 38,394 km^2 roughly measuring 140 km north to the south and 275 km east to west with altitudes varying from 100 metres above sea level (masl) in the southern sub-tropical region to 7550 masl in the Northern alpine region (Tshering and Tamang, 2004). By virtue of its geographical location, the country comprises of two major biogeographic realms. These two biogeographic realms are Indo-Malayan region in south east and Palearctic region in northwest (BAP, 2009). Such fact ensured rich biodiversity and put the country on a pedestal of being one of the ten biological hotspots in the world (Chhopel, 2014). The country comprises of four major river systems; Dangme Chhu (Manas), Punatsang Chhu (Sunkosh), Wang Chhu (Raidak) and Amo Chhu (Toorsa) from east to west (Gurung *et al*., 2013). In addition, there are several small river basins which includes Samtse Area multi-river, Gelegphu Area multi-river, Samdrup Jongkhar Area multi-river, and Shingkhar-Lauri multi-river (BAP, 2009). Therefore, in total, 7,200 km length of river network is estimated (Petr, 1999). Moreover, NEC (2011) reported presence of 2,674 lakes in the country. Perennial flow of water in the swift flowing rivers and fair climatic condition with all rivers running north-south through steep terrains provide an ideal setting for harnessing hydropower energy (Tshering and Tamang, 2004). Meanwhile, east-west flowing rivers provide much of the water required for irrigation (Chhopel, 2014). In synchronous with the economical and agriculture services provided, Dubey (1978) reported that the aquatic fauna in the country is predominated by coldwater and torrential stream fauna except in foothills. Gurung and Thoni (2015) reported that there is 109 fish species in the country and the number continues to increase.

Although, the conservation of biodiversity and ecosystem in the country is given importance through unique social, cultural and development philosophy of the Gross National Happiness - GNH, (NEC, 2011), Bhutan has estimated hydropower potential of 30,000 MW in Bhutan's Power System Master Plan (2003-22), which makes efforts to harness all hydropower energy

potential. This is however of concern from the environmental and ecological perspectives. Tshering (2011) stated that, ever since the country started adoption of modernization in 1960s, river system of the nation played a pivotal role for developmental activities such as drinking, irrigation, industrial use, and generating hydropower energy. With increase in pollution of freshwater system through point and non-point sources, the quality of water can also be undermined and the habitat of aquatic fauna damaged.

The undergoing construction of Tangsibji hydropower (THyE) at the proposed study site will have various impacts on aquatic life and riparian habitat. Rajvanshi *et al.* (2012) mentioned that, although reservoirs positively affect certain fish species by increasing the area of aquatic habitat, the net impacts are generally negative as the dam blocks upstream fish migration and down river passage. Similarly, the construction of access road and residential accommodation will have adverse impact on riparian vegetation and quality of water. Quammen (1996) mentioned that humans have "succeeded extravagantly at the expense of other species" and played a major role in determining the fate of ecosystems around the world. Therefore, this research aims to create the baseline information on ecosystem of Nika Chhu in local scale before the developmental activities over shadows the value of natural freshwater ecosystem of Nika Chhu.

Orgin of Works

As human population is growing and change of land use is taking place day by day. Forest are converting into farmland, road construction, building institutional structures. Thus more categories of pollution occur in our streams. Such pollution impacts the overall freshwater ecosystem (Maul, 2004). It is clearly mentioned by Eby *et al*. (2009) that the ecological service provided by the fresh water is crucial for the healthy and happy human society. However, Gurung *et al*. (2013) stated that the list of fishes reported are underestimate for freshwater fish diversity of country with lesser sampling intensity. Similarly, Dorji and Wangchuk (2014) asserted that the freshwater ecology and fish habitats have not been well studied in the country. Also, Tenzin (2006) stated that one way of assessing freshwater ecology is through assessing the Bio-indicators like fish and other organism with its ecology.

Recent undergoing construction of THyE on Nika Chhu may have some adverse impact on the freshwater ecology. As Tshering & Tamang (2004) mentioned [“while hydropower

development involves non-consumptive use of water, its diversion and damming can cause undesirable environmental and social impacts"]. Hence, the construction of hydro power on Nika Chhu has cause the concern over ecologist and conservationist about loosing freshwater ecosystem and its biodiversity before studied or recorded. Therefore the need to initiate and create a scientific baseline data about freshwater ecologyof Nika Chhu is highly valuable.

Objectives

This study aims to

- Assess the diversity and distribution of fishes, macro-invertebrates and butterfly along Nika Chhu
- Identify the different habitats for fishes, macro-invertebrates and butterflies along the Nika Chhu
- Create awareness about the biodiversity of fish, macro-invertebrates and butterfly, different habitats, status of Nika chhu ecology and importance of conserving the freshwater ecosystem among different stakeholders like communities of two gewog (Block), Staff of local government, Jigme Singye National Park and Nika Chhu Hydro Power.

Scope of the project

In synchronous with the agreed objectives and problems, this research will serve as a information for diversity and ecology of fishes, macro-invertebrates and butterflies in Nika Chhu. It can serve as prediction for some ecological values and conservation strategies. This study will provide an holistic information on Nika Chhu freshwater ecosystem, through which the decision makers, Government and Local communities can have a varied options in win-win situation for implementing development activities without compromising the conservation of the river ecosystem. This research project will contribute in terms of adding aquatic ecosystem information in the nation. The findings can become a basis for making right policy decisions, rules and regulations, and implementing developmental by policy makers, ecoligists, and various agencies like the National Environment Commission and Department of Forest and Park Services.

SECTION II: MATERIALS AND METHODS

Study Area

Nika Chhu is a tributary of Mangdi Chhu which eventually joins the Drangme Chhu river basin. It originates from the snow capped high mountain ranges of Gangkar Puensum. The river is located in the central part of the country. It flows along the Sephu *gewog* under Wangdiphodrang district as upper stream and Tangsibji gewog under Trongsa district as lower stream. Along the stream, 14 villages of 2 gewogs exist. With the nature of settlements along the stream, the stream plays a vital role. It serves different purpose for the livilihood of communities, such as drinking water, irrigation and non measurable aquatic ecosystem benefits. With existing forest dominated by cool broad-leaved species, the river serves as an ideal place or habitat for many wildlife, birds, and fishes.

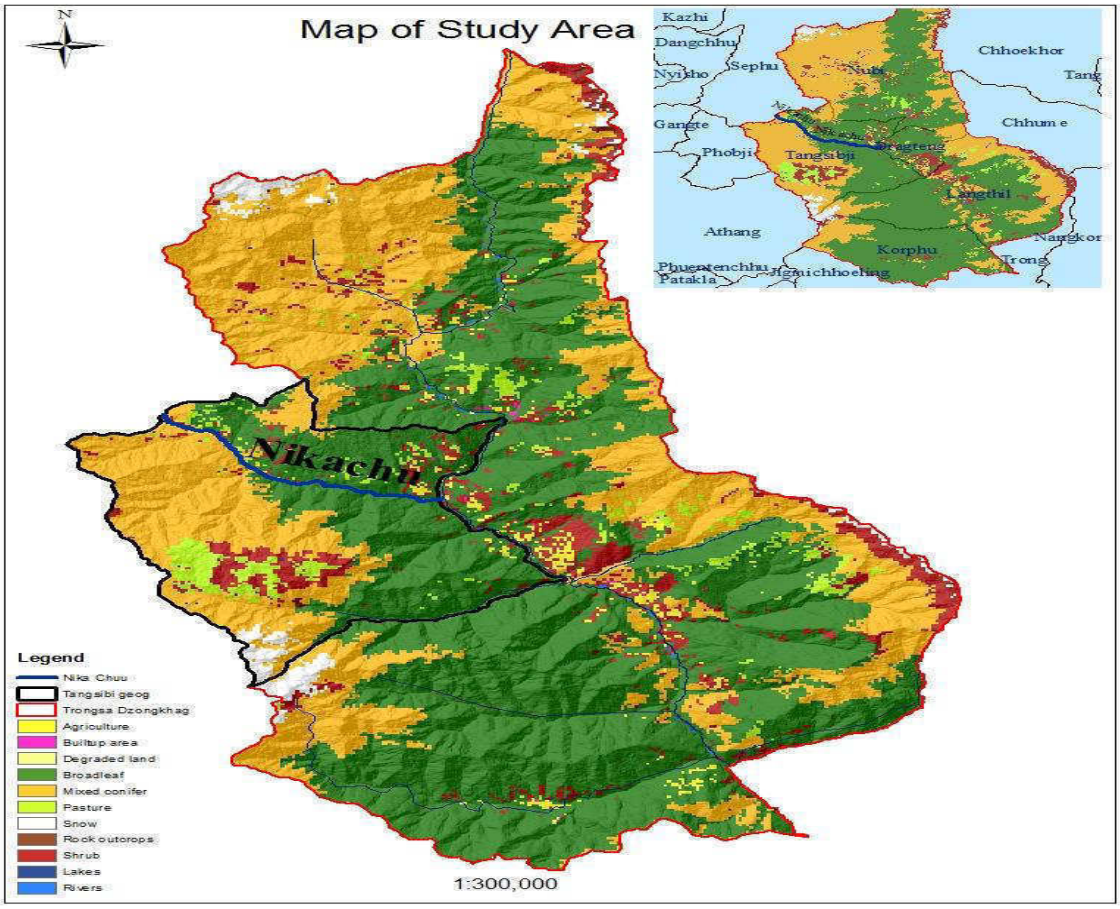


Figure 1. Study area showing Nika Chhu

Nika Chhu stream is divided into three sections and various offices under Department Of Forest and Park Services (DOFPS) look after it. The upstream falls under Wangchuck National Centennial Park. In the midstream, each bank falls under the juridiction of Wangdi forest division and Zhemgang forest division respectively, where as the lower steam bank falls under Jigme Singye Wangchuck National Park and Zhemgang forest division. The stream was divided into two parts, upper and lower stream from the perspective of dam construction by Tangsibji Hydro Energy limited (THyE) project.

Lower stream

The lower stream for the study was designated from Mangdi Chhu Nika Chhu confluence (N: 27°26'01.5", E: 90°27'48.7") to till Nika Chhu Tsheringma drup Chhu confluence (N: 27°26'99.7", E: 90°22'29.4"). The presence of a gorge, high velocity of water, large boulders and bedrocks on the riverbed reminds the harsh condition of the river. Variables like altitude, temperature, pH, conductivity, TDS, and canopy coverage were recorded as additional information of the habitat. Presence of high forest dominated by *Quercus semicarpifolia* Rees, *Q. gluaca* Thunberg, *Q. griffithii* Hooker and Miquel, *Alnus nepalensis* Don, *Angelhardia spicata* Lech. ex Blume and *Castronopsis hyterix* A.DC, 1863 without any settlements along the river bank makes the area much suitable as wildlife habitat. Pug marks of Tiger, sloth bear, and leopard are found along the river stretch on sands. Further, we have seen many species of birds, of which Rufous-necked hornbill (*Aceros nepalensis* Hodgson, 1829) is also present.

Figure 2. Lower stream study area

Upper stream

The Upstream study site was selected from the dam construction site of Tangsibi Hydro Energy limited (THyE) with the cordinates reading of N: 27°27'03.9", E: 90°22'06.7" to till Chhuserbu with coordinates of N: 27°31'.08.2", E: 90°16'58.7". The stream is relatively wide and shallow, and is predominated by cobble bottom, with several areas of gravel and coarse sand. Similar to the lower stream, additional information were recorded for this stretch of the rivers as well. This information will be discussed thoroughly in the result section. *Quercus semicarpifolia*, *Pinus wallichiana* A.B. Jacks, *Populus ciliate* Wall. ex Royle and *Rhododendron kezangiae* Long and Rushforth, are the dominating species along the bank of the stream. Human settlements are present along the river valley. The harmonic relation between the aquatic ecosystem and society can be noticed through various ways. Building stupa (Chorten) on the bank of stream, adoption of stream by Chendepji Community Primary School and extraction of power energy through mini hydropower are some examples of such relationship.

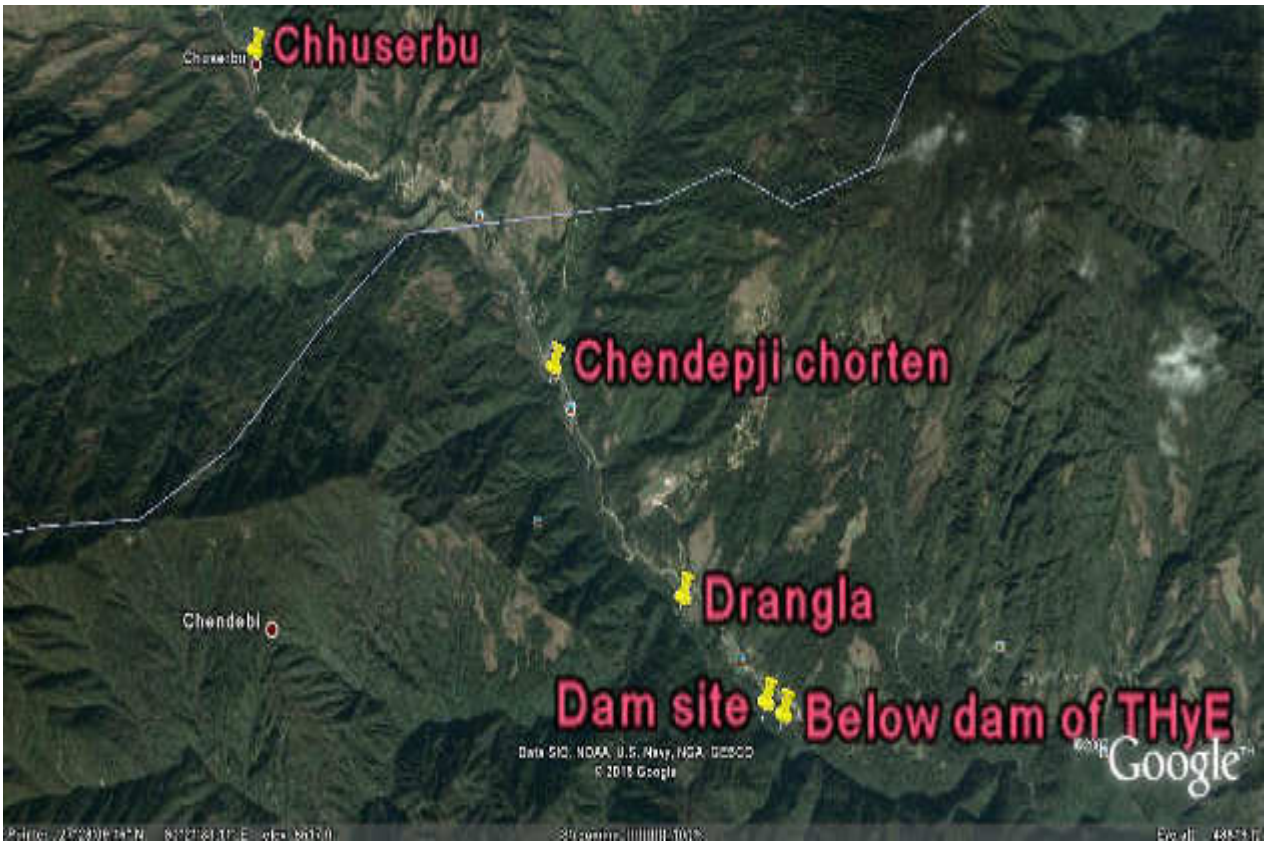


Figure 3. Upper stream study area

Table 1. Dominating vegetation along the Nika Chhu

Binominal name	Genus	Family	Order	Local Name
Quercus semecarpifolia	Quercus	Fagaceae	Fagales	Gumseng
Quercus glauca	Quercus	Fagaceae	Fagales	Creseng
Castronopsis hystrix	Castanopsis	Fagaceae	Fagales	Shaquaw
Alnus nepalensis	Alnus	Betulaceae	Fagales	Gangseng
Quercus Griffithii	Quercus	Fagaceae	Fagales	Pising
Rhododendron kesangiae	Rhododendron	Ericaceae	Ericales	Aeto meto
Populus ciliata	Populus	Salicaceae	Malpighiales	Jashing
Pinus wallichiana	Pinus	Pinaceae	Pinales	Changseng
Salix wallichiana	Salix	Salicaceae	Malpighiales	Changma

General Materials used for ecological parameters

Global Positioning System (GPS) was used mainly to obtain the coordinates of plots but was even used to obtain other information of the plots. Occationally, we faced difficulties, as we couldnt acquire GPS readings. In such senario, we used Suunto Compass and Suunto Clinometer to obtain the aspect and slope respectively. Measuring tape played a vital role in measuring the depth and width of stream, and it was used while laying out the plots for vegetation study as well. Diameter tape was used to measure the diameter of trees. Digital camera was used in the field to get the first hand digital images before getting lost of colour and texture, which generally gets lost while perserving specimen in formalin.

Data analysis

Shannon Diversity Index takes care about the species richness and abundance. Therefore, while deriving Shannon diversity index, both species richness and abundance were calculated.

Shannon Diversity Index (*H'*)

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

Where,

H'= index of species diver

Ln = natural logarithm or log

S = species richness (total number of species present in a plot or in the study area)

Pi = proportion of individuals belonging to an i^{th} species in a plot or in a study area or is the number of individuals of a species divided by the total number of individuals of all

Species abundance (*A*): number of individuals of a species present in a plot or in a given study area.

Pearson correlation and mean comparisons through independent sample *t* test in SPSS software was executed to check the associations and significant differences amoung the variables. Other descriptive statistics such as cross tabulations and frequency distribution were also used. Graphics and visual interpretation of results were developed using Microsoft Excel 2007.

SERYA (Golden Fish): The symbol of Fearless in all living beings.

SECTION III: FISHES

Abstract

Studies on diversity and distribution of freshwater fish in the country are very low. Need of such studies have been highlighted by many fish biologists and ecologists from within the country. This section of report deals with diversity and distributions of fish along the Nika Chhu stream. It was conducted in two phases; in January and late March to early April, 2016. Temporary stream diversion and use of minimum voltage electric fishing in combination with catch–and-release method with various nets and locally improvised techniques were used during the field survey. A total of 244 individuals were enumerated during entire period of study, comprising 178 individuals of *Salmo trutta* Linnaeus, 1758, 65 individuals of *Schizothorax richardsonii* (Gray 1832), and 1 *Creteuchiloglanis* sp. Zhou, Li and Thomson, 2011. In January, *Salmo trutta* represented 63% (n = 41) of total abundance and *Schizothorax richardsonii* represented 37% (n = 24) of total. Later in the month of March–April, the species composition has increased to three with addition of *Creteuchiloglanis* sp along with existing *Salmo trutta* and *Schizothorax richardsonii*. *Salmo trutta* represented 76.2% (n = 135) of total number, followed by *Schizothorax richardsonii* with 23.2% (n = 43) and *Creteuchiloglanis* sp by 0.6% (n = 1). Shannon diversity index (*H'*) was calculated to determine the diversity index. The *H'* values for the month of January and March were 2.363 and 2.825 respectively. Morphometric measurement was measured for each species of fish. Independent sample t test shows the significant (p <. 05) between the morphometric readings of species in two phases. Lower section of the river adjoining Mangdi Chhu had a distribution of *Schizothorax richardsonii* only and the upper stream had a distribution of *Salmo trutta* and *Creteuchiloglanis* sp. While examining the distribution along various habitats, the *Schizothorax richardsonii* was found mostly distributed near the confluence (n = 24) and *Salmo trutta* was found in run habitat (n = 57). No significant (p > .05) association was found between the species, habitat types and environmental factors. Such observation could be attributed to lesser sampling area and shorter period of study

Key words: Catch-and-release, *Creteuchiloglanis* sp, Distribution, Diversity, *Salmo trutta* Linnaeus, 1758, *Schizothorax richardsonii* (Gray 1832), Shannon diversity index (*H'*)

Historical background on studies of fishes in Bhutan

McClelland (1839) on his book titled "Indian Cyprinidae" recorded two species of fish found from Bhutan by William Griffith as *Oreinus guttatus* (*Schizothorax richardsonii*) and *Platycara maculata (Balitora brucei* Gray, 1830*)*. Thoni and Hart (2015) repatriated the *Cobitis boutanensis* McClelland, 1842, of Griffith's collection of 1842 *to Aborichthys boutanensis* (McClelland, 1842)*, which* was infact collected from Bhutan rather than from Afghanisthan. Dubey (1978) carried out study on fish of Bhutan recording a total of 42 species with dominant species by Asla, a local trout (*Schizothorax progastus*). Petr. (1999) reported 41 species of fish in the country with 8 exotic species. With discovering of *Triplophysa stoliczkae* (Steindachner, 1866) from Lingzhi reported by Dema (2007), the number was assumed to be almost 50. Later NEC, (2011) formally reported 50 species of freshwater fishes including 8 introduced species, mentioning indigenous fishes as Himalayan trout, *Barilius* sp., and mahseer, *Tor tor.* The first intensive work on fish of Bhutan was published by Gurung *et al.* (2013) as "an annotated checklist of fishes from Bhutan" reporting with 91 species of fishes**.** Tshering (2014), reported the increasing number of fish diversity from 50 to 93 with discovering of a new species of torrent catfish from Khalingchhu, Khaling Torrent Catfish *(Parachiloglanis bhutanensis* Thoni and Gurung, 2015*)* by Gurung and Thoni. Later, Gurung and Thoni (2015) reported 109 fish species and mentioned that the number of fishes will continue to increase.

Roles of fishes

Food sources and livelihood improvement: A global perspective

With rapid increment in the world's population, many people have started depending on fisheries and aquaculture for food and as a source of income. About 158 million tons of fish was produced in 2012, which is more than 10 million tons compared to that of 2010 (FAO, 2014). Fish provides food and a livelihood for millions of the world's poorest people, and also contribute to the overall economic wellbeing (IUCN, 2015). In the Mekong River basin alone, over 55.3 million people depend on freshwater fish for nutrition and livelihoods, with an estimated average fish consumption of 56.6 kg/person/year (Baran *et al*., 2007). It is estimated that freshwater fishes make up more than 6% of the world's annual animal protein supplies for humans (FAO,

2014). Moreover, besides supplementing as a dietary source, the fish and its components have created a space for employment.

Food sources and livelihood improvement: A national perspective

The fourth state of nation report of 2012 highlights the importance of freshwater fishes in the Bhutanese context. It was stated that within 2010-2011 plan period, the production of fish was 45 metric tons. Realizing the importances and scope of the fishes in the country, the government has legalized and supported establishment of few capture fishery groups in the country. Among these are the Hara Chhu Capture fisheries management group established in 2010 and Berti Capture fisheries management group established in 2012, which aimed at increasing production of fish, improvement of livlihood and in generating employment.

Ecological services provided by fishes

Consumption of organisms by fish is a natural phenomenon, which actually regulates the trophic structure and nutrient balance of aquatic ecosystem. Therefore, it influences the stability, resilience, and food web dynamics of aquatic ecosystems (Holmlund and Hammer, 1999). Further, IUCN, (2015) added that the fish plays a vital role in regulating other services such as carbon flux and sedimentary process. Fish communities can regulate the carbon-fixing capacity of lakes through balancing the nutrient-rich organism in the lakes or stream. Therefore, indirectly it helps in maintaining the flux of carbon between a lake and the atmosphere. In the context to regulating the sedimentary process, Holmlund and Hammer (1999) asserted that the bioturbation process of fish, which literally means a physical disturbance of sediments resulting due to foraging, burrowing or spawning activities by fishes, maintains the fish habitats. During the process, the fish removes many aquatic macrophytes, sediment particles and other organic matters. This in turn enables the sedimentation process in continuity at various rates. IUCN, (2015) mentioned that the fish as a bioindicator is another important ecological value of fish. Some fish communities and specific species are excellent indicators of biological and ecological integrity due to their continuous exposure to aquatic conditions. Fishes display many changes according to biotic responses, such as changes in growth, distribution and abundance related to water pollution, habitat degradation, eutrophication, organic enrichment, chemical toxicity,

thermal changes, and food availability. All these processes indicate the ecological health of the aquatic environment.

Materials used for studying fishes

Various types nets such as cast net, gill net and locally produced nets were used to catch the fishes. A Uninterrupted Power Supply (UPS) of 12 volt with alternate current was deployed for electric shocking occasionally. In situ water quality parameters such as pH, temperature, conductivity and TDS were determined by using a multi parameter water testing kid (Oakton PCS testr 35). For identification of fish species, Annotated checklist of freshwater fish of Bhutan and Fishes of Bhutan: a preliminary checklist was used in field.

Methods used for Fishes

To assess the diversity of fishes, every possible ways and methods were incorporated. Cast net, gill net, and locally improvised nets and techniques used by local fishermen were used (Shrestha *et al*., 2009). According to the habitat type of stream section, temporary diversion with locally availiable materials like stone and twigs was carried out for several numbers. In addition, a mild electro fishing equipment using UPS was also employed.

To assess the distribution of fishes along the stream, the systematic sampling plots were fixed at every 200 meter transect (Tshering, 2011). In total, 96 sample plots were collected and assessed for over the two different timings of Jan-Feb and March-April, 2016 (Figure 1). Catch-and release method (Tshering, 2011), was conducted in every plots. In each plot, five times throw of cast net with three minutes gap between every throw was followed. In situ water quality parameters were measured at each sampling plot. The pH, temperature, conductivity and TDS were determined by using a multi parameter water testing kid (Oakton PCS testr 35). Stream depth and width were measured physically through stream. Further, information like morphometric measurement of fish caught – such as weight, total length (TL) and standard lenght (SL) were also collected.

Specimens collected were identified in the sampling plots. Moreover, expertise from College of Natural Resources was consulted for confirmative identitifcation. Digital camara was used in every occassion to have a record of any works digitally. Later, the specimen were transported to the College of Natural Resources for proper perservation and future records.

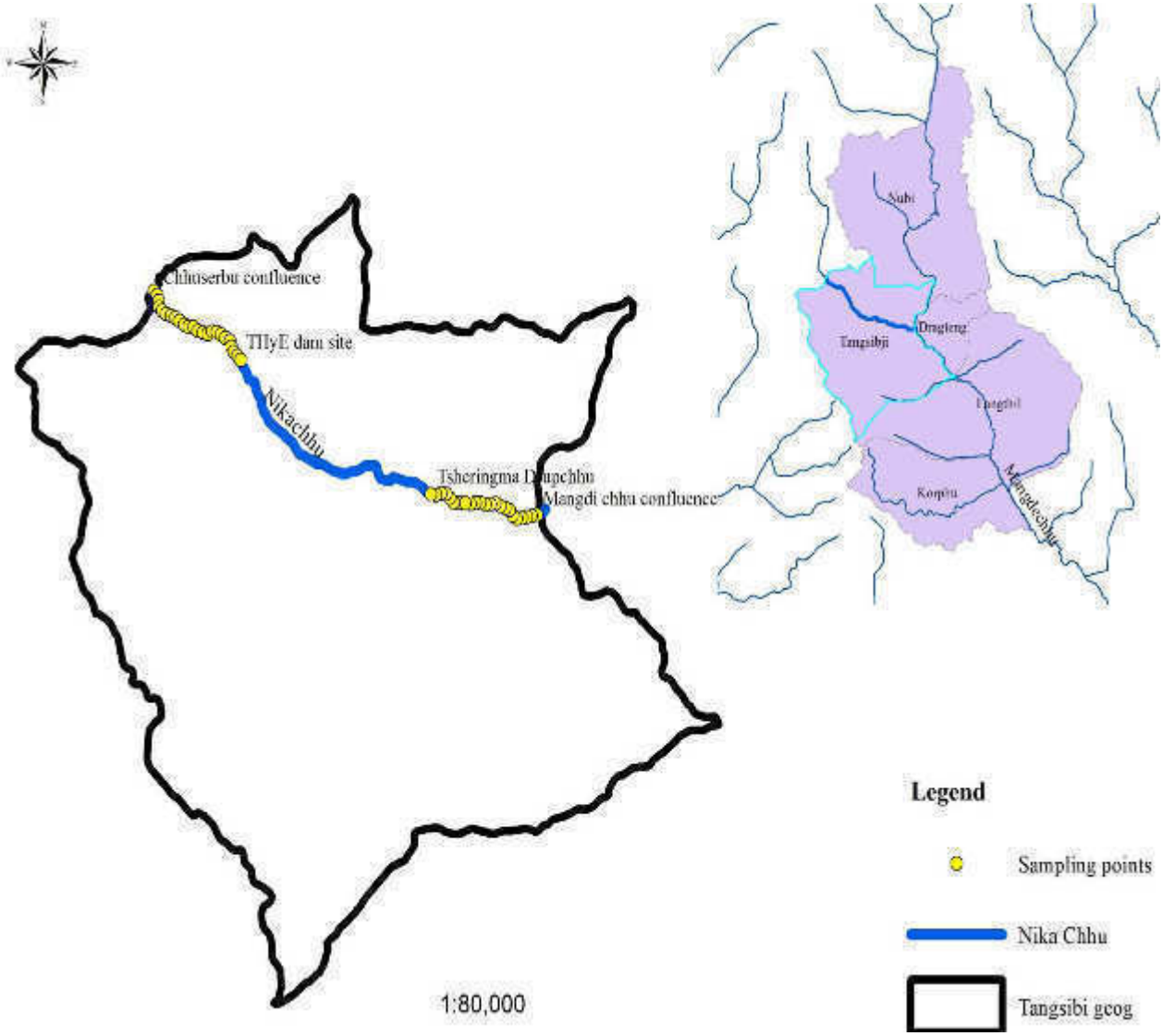


Figure 4. Study area showing the sampling point

Results

Species abundance and Species composition

Species abundance can be defined in many ways. In simple, we can define as a number of individuals per species at a given area (how much of individuals in every species at given area). Similarly, species richness (Composition) can be defined as a number of different species found in a given area (How much of species at given area). However, many of us seems using this two different words for one purpose. In fact, species richness is simply a count of species, and it does not take into account the abundances of the species.

A total of 244 individuals were enumerated during the entire period of study. It comprises of 178 *Salmo trutta,* 65 *Schizothorax richardsonii* and 1 *Creteuchiloglanis* sp as shown in Figure 5. Survey was conducted twice (January and late March–early April, 2016), in which the abundance and species composition of fishes were different. In the month of January, species composition was only two with *Salmo trutta* and *Schizothorax richardsonii*. *Salmo trutta* represented 63% (*n* = 41) of total abundance and *Schizothorax richardsonii* represented 37% (*n* = 24) of total. Later in the month of March-early April, species composition increased to three with addition of *Creteuchiloglanis* sp with existing two fish. *Salmo trutta* represented 76.2% (*n* = 135) of the total, followed by *Schizothorax richardsonii* with 23.2% (*n* = 43) and *Creteuchiloglanis* sp by .6% (*n* = 1).

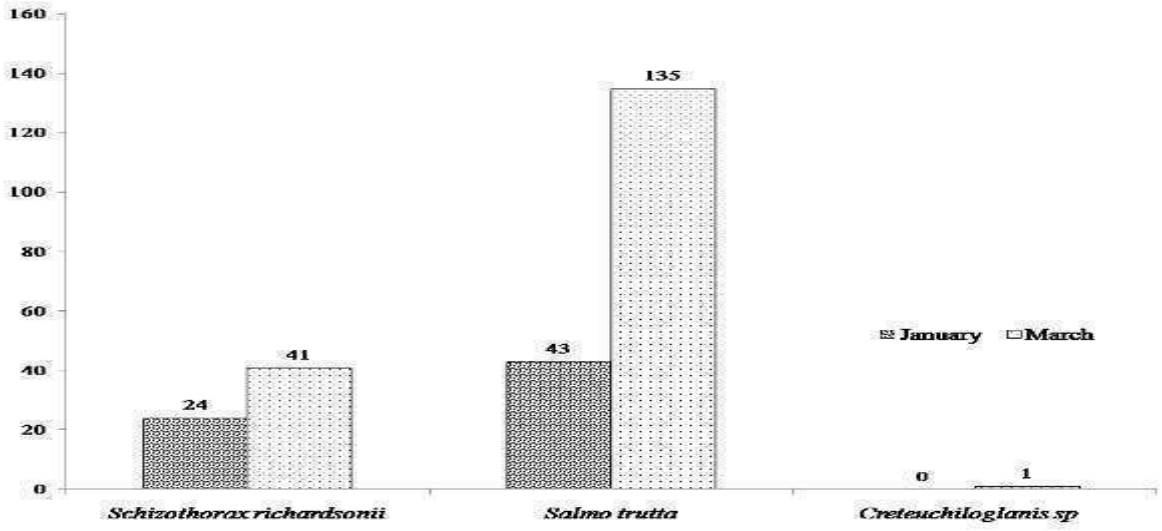


Figure 5. Abundance of fishes in Nika Chhu in two phases

Species Diversity

During the entire period of survey, the species composition of the fishes in the study area was three with *Salmo trutta* dominating the area. The value of Shannon diversity index (*H'*) was calculated according to the two phase of survey (January and March). After computing the whole samples (48 for each month), the *H'* value was derived. The *H'* value for the month of January was 2.363 and for the month of March were 2.825 as depicted in Figure 6.

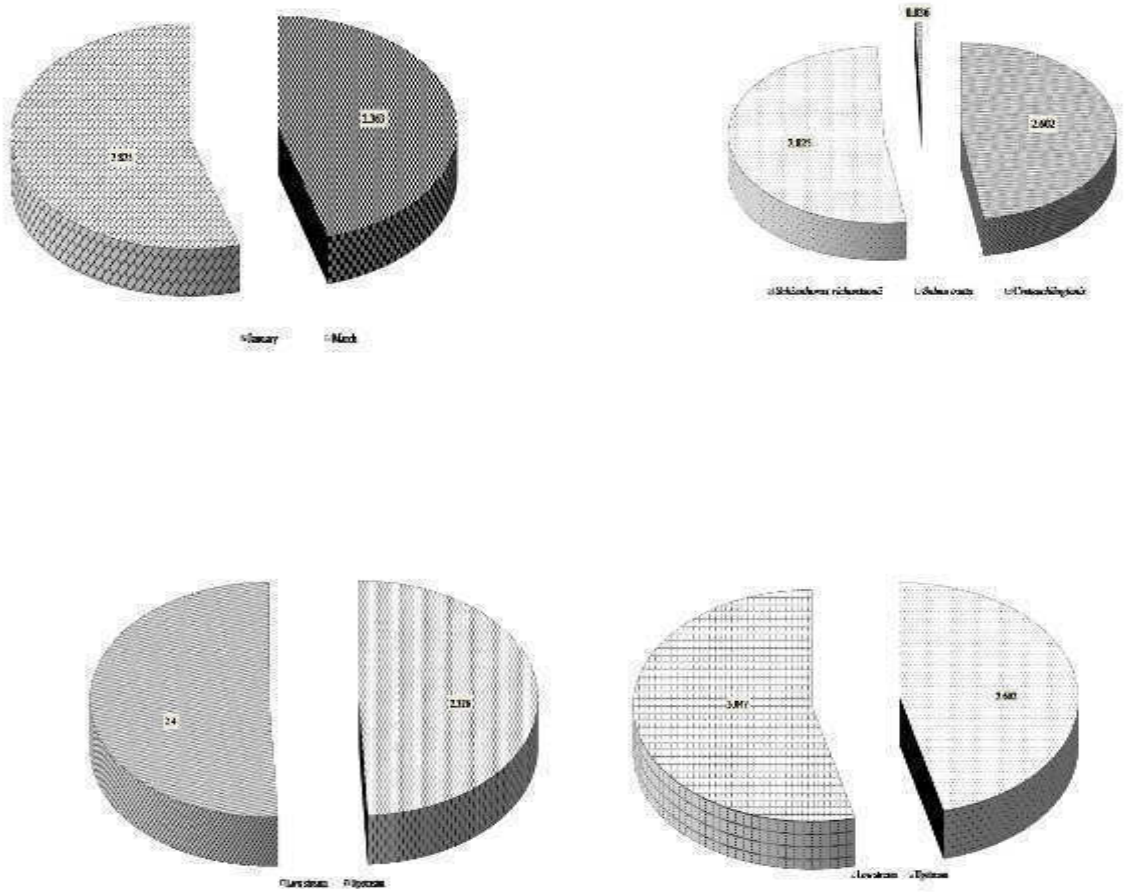


Figure 6. Diversity in various seasons

As the stream was divided into two zones of upstream and low stream, the value of *H'* for various stream zones was also derived. Of all, the highest Shannon diversity index (3.047) was found at upstream zone in the month of March as shown in Figure 6. Lowest Shannon diversity index (2.326) was found at low stream zone in the month of January as referred in Figure 6. Independent sample *t* test confirmed that there was no significant difference in diversity index between the upstream and low stream; $t_{(1)} = 2.48$, $p > .05$. Kerkhoff (2010) explains that the Shannon diversity values generally ranges between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. In this context, the Shannon diversity Index (*H'*) of the Nika Chhu fishes ranged between the value of 2.363 and 2.825 over the two times survey, which cannot be considered to be high but is higher than the minimum of 1.5. Pearson correlation between species composition and Shannon diversity Index (*H'*) had a strong positive association; $r = 1$, $p < .01$.

Morphometric measurement

Although various measurements were taken to describe the morphometric data of fishes, only the basic standard measurements were used to describe the fish in this study. Author has taken in account of weight, total length (TL) and standard length (SL). Weight stands for overall weight of fish measured in kilogram, TL refers to the length of a fish measured from tip of snout to the tip of longer lobe of a caudal fin and SL refers to the length of the fish measured from the tip of snout to the posterior end of the last vertebra.

Table 2. Morphometric measurements of *Salmo trutta* and *Schizothorax richardsonii*

Species	Standard measurement	Max	Min	Mean	SD
Salmo trutta	Weight (kg)	0.4	0.04	0.13	0.07
	TL (cm)	40	10.3	19.82	5.4
	SL(cm)	32	8	16.65	4.74
Schizothorax richardsonii	Weight (kg)	0.35	0.02	0.12	0.07
	TL	32.5	9	19.72	8.19
	SL	6	25	15.99	6.64

Table 3. Morphometric measurements of *Creteuchiloglanis* sp

Species	Standard measurement	Measurement
Creteuchiloglanis sp	Weight (kg)	0.08
	TL	155.61
	SL	139.42

Table 2 and 3 provides the standard measurements of fishes studied. Out of 176 individuals of *Salmo trutta,* the maximum weight measured was 0.4 kg and the minimum was 0.04 kg. Mean weight of *Salmo trutta* was 0.13 kg with a *SD* ± 0.07 kg. Likewise, maximum total length was 40 cm and minimum 10.3 cm, with a mean of 19.82 cm (*SD* ± 5.40). Similarly, the standard length measured a maximum of 32 cm and minimum of 8 cm with a mean of 16.65 cm (*SD* ± 4.74). Additionally, for 65 individuals of *Schizothorax richardsonii*, weight was 0.35 kg with a minimum of 0.02 kg and a mean of 0.12 kg (*SD* ± 0.07). Maximum total length was 32.5 cm with a minimum of 9 cm, and a mean of 19.72 cm (*SD* ± 8.19). Maximum and minimum standard lengths were 25 cm and 6 cm with a mean of 15.99 cm (*SD* ± 6.64). *Creteuchiloglanis* sp. had a weight of 0.08 kg with a total length of 15.56 cm and standard length of 13.94 cm.

Distribution of fishes in Nika Chhu

Distribution is an area or site occupied by individuals of an interest. In this study, the habitat type of Nika Chhu was classified into four types mainly depending on water depth, water velocity, gradient, flow regime, substrate, and presence of adjoining stream. Stream was divided into pool, run, cascade, and confluence. Results are presented based on how the species differed in distribution and what parameters constituted the habitat types.

Distribution of Schizothorax richardsonii

As discussed earlier, due to the presence of a waterfall, distribution of this species was absent above the waterfall. Lower stream adjoining Mangdi Chhu had a distribution of *Schizothorax richardsonii*. Environmental factors present in the habitat of *Schizothorax richardsonii* are listed in Table 4.

Table 4. Environmental factors of the habitats occupied by *Schizothorax richardsonii*

Environmental factors	Minimum	Maximum	Mean	SD
Altitude (masl)	1405	1852	1635.83	133.99
Temperature (°c)	4	15.8	10.06	4.7
pH	6.41	7.2	6.95	0.19
Depth of river (m)	0.9	1.9	1.36	0.28
Width of river (m)	28	38	34.1	3.05
Canopy coverage (%)	2	4	2.79	0.84

Canopy coverage index – 1 = >25%, 2 = 26-50%, 3 = 51-75%, 4 = 76-100%

In the entire study period, 65 individuals of *Schizothorax richardsonii* were examined for its distribution in the four different habitat types. Out of 48 plots, only 12 plots representing 25% of total plots were found with fish. Remaining 36 plots representing 75% of total plots had no fish as shown in Figure 7. Presence of fish number in 25% (n = 12) plots varied among the plots, which ranged from 1 to 5 individuals. Mean number of fish present was 2.40 (SD ± 1.29).

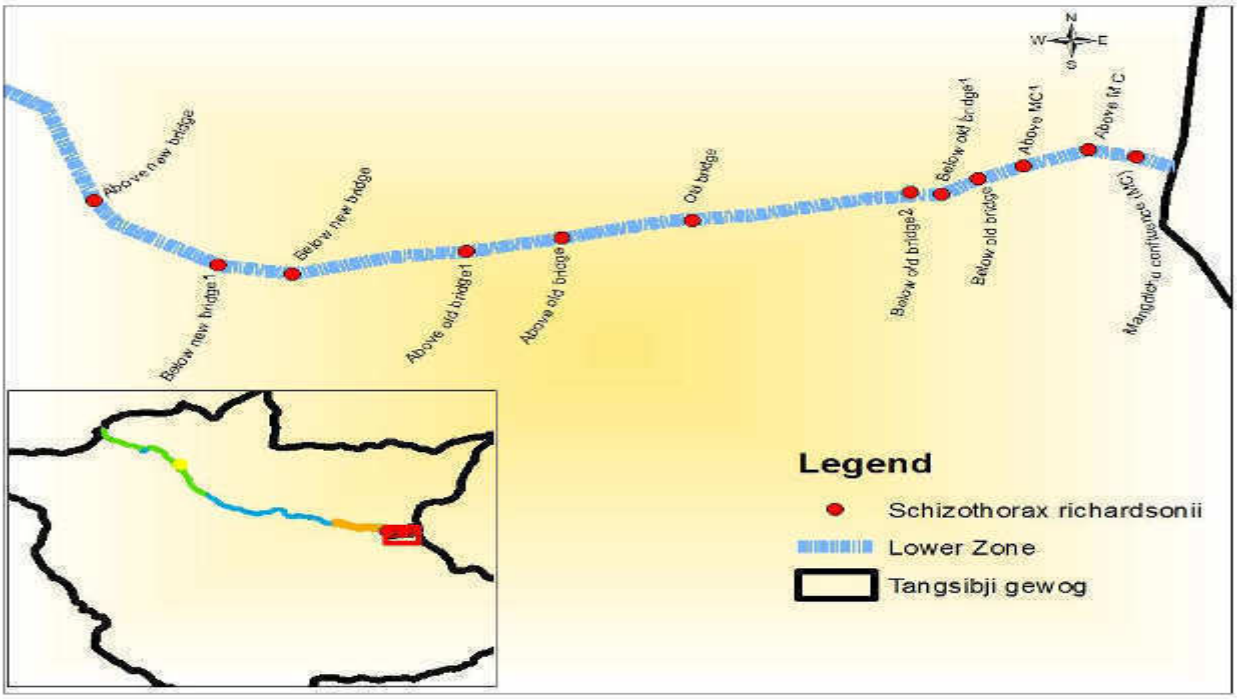


Figure 7. Location of *Schizothorax richardsonii*

While examining the distribution of *Schizothorax richardsonii* in various habitat types (Figure 8), the presence of individuals in various habitat type ranges from a maximum of 24 to a minimum of 12. Highest number of individuals were found distributed in confluence habitat (n = 24). Lowest number of individuals were found distributed along the cascade habitat (n = 12). Pool habitat had 16 of individuals and the run had 13.

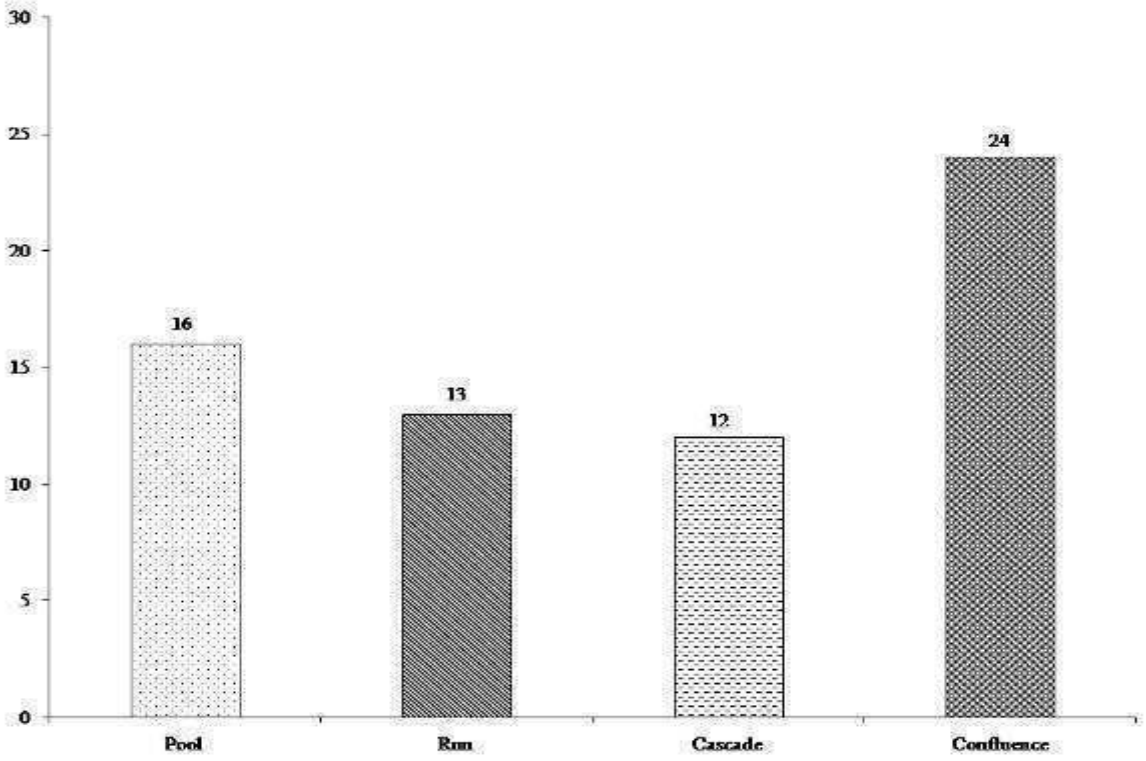


Figure 8. Total catch of *Schizothorax richardsonii* in various habitats

Distribution of Salmo trutta

Upper stream consist of *Salmon trutta* and *Creteuchiloglanis* sp. Overall environmental factors of the habitat are shown in Table 5. The altitude of the upstream habitat occupied by *Salmo trutta* and *Creteuchiloglanis* sp. ranges from 2234 – 2631 masl. The pH ranges from 7 – 7.4. Temperature ranges between 2 – 13.2 ^{0}C. Depth of stream ranges from .2 – 1.5 meter. Width ranges from 9.5 – 38 meter. Canopy coverage comprises from 1 – 75 %.

Table 5. Environmental factors of the habitats occupied by *Salmo trutta* and *Creteuchiloglanis* sp

Environmental factors	Minimum	Maximum	Mean	SD
Altitude (masl)	2234	2631	2438.25	103.75
Temperature (°c)	7	7.4	7.15	0.13
pH	2	13.2	8.2	3.76
Depth of river (m)	0.2	1.5	0.75	0.35
Width of river (m)	22	38	20.14	8.9
Canopy coverage (%)	1	3	1.54	0.58

In the entire study period, 178 individuals of *Salmo trutta* was caught and examined their habitat distribution. Out of 48 plots, only 36 plots representing 75% of the total plots were found with fish. Remaining 12 plots representing 25% of total plots were found with no fish. Number of fish present in 75% (n = 36) plots differ from 1 to 12 individuals as shown in Figure 9

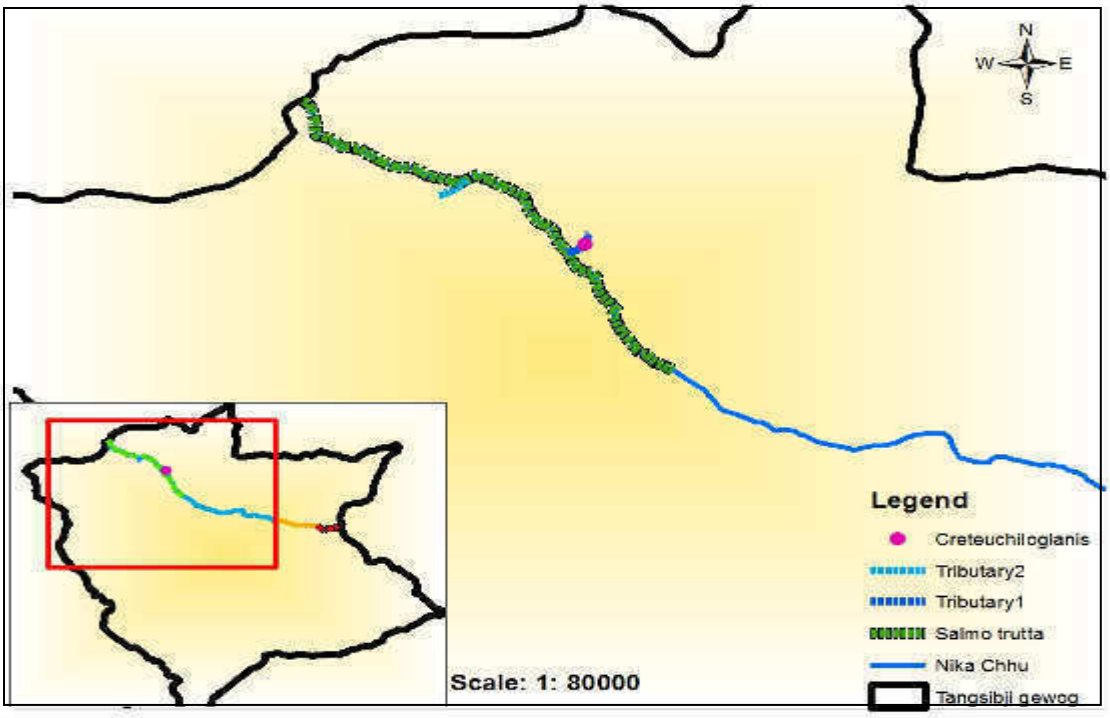


Figure 9. Location of *Salmo trutta* and *Creteuchiloglanis*

Mean number of fish present was 4.9722 (*SD* ± 2.92). Distribution of *Salmo trutta* in different habitat types (Figure 10), ranges from a maximum of 56 to a minimum of 37 individuals. Highest number of individuals were found distributed in run habitat (n = 57). Lowest numbers of individuals were found distributed along the cascade habitat (n = 37). Pool and confluence habitats have 40 and 42 individuals respectively. Unlike *Schizothorax richardsonii*, *Salmo trutta* was observed preferring run habitat than other habitats. Run habitats consist of wide width, shallow depth, and low current and direct sunlight.

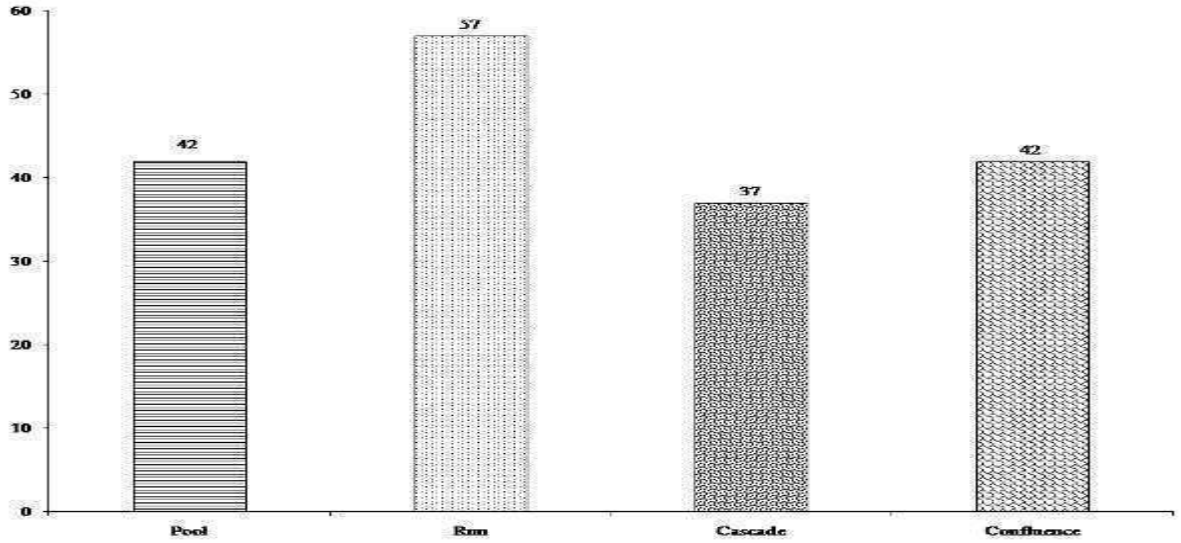


Figure 10. Total catch of *Salmo trutta* in various habitats

Discussion

Species abundance, species composition and diversity

Less diversity and species composition in the study area can be attributed mainly due to the presence of a water fall below the proposed dam site and the presence of an invasive exotic species *Salmo trutta.* Environment and Social Impact Assessment (ESIA) of Nika Chhu Hydropower Project (2014) reported the presence of *Schizothorax progastus*, *Schizothorax richardsonii*, *Acrossocheilus hexagonolepis*, catfish, carp, and some smaller resident fishes in Mangdi Chhu. Although the fishes can migrate from main river to its tributaries, migration of fishes from Mangdi Chhu to upper stretch of Nika Chhu was not observed much. Several waterfalls are present in the lower part of stream and one of the waterfalls near *"Takshang Sangmey"* is higher than 30 metres. Burrill (2014) reported that distribution of fish is determined primarily by stream connectivity. If the fishes are stocked in a stream, where there isn't any

connectivity or a presence of natural barriers such as waterfalls and cascades which exceeds more than 3 meters in height, the likelihood of their spread is greatly diminished. Furthermore, given the relatively high altitude, cold water, and rough conditions in Nika Chhu, these environmental factors could have played a role in low fish diversity.

Salmo trutta belongs to the order Salmoniformes and are classed with the family Salmonidae. This species is native to Europe, but have a native range in North Africa and Western Asia. It was imported and introduced in the rivers of Bhutan in 1940 (Gurung and Thoni, 2015). It is distributed mostly in the altitudinal range of 1000 – 3500 meters above sea level (Gurung and Thoni, 2015). Burrill (2014) stated that Brown trout have a nearly worldwide distribution and it is increasing in its distribution. Some unique characteristics of *Salmo trutta* such as high capacity of tolerance to low temperature (0.4^{o}c – 26^{o}c) and high pH range from 5 to 9.5 makes them ideal to spread faster. Moreover, with age, *Salmo trutta* becomes more carnivorous and tend to target larger prey species such as other fishes (including cannibalism), mice, small birds, and crayfish. This feeding behavior results in competition between *Salmo trutta* and other species of interest, given their predatory nature. Further, capacity to mature early leads them to early exploitation of resources, which result to increased likelihood of faster establishment.

Morphometric measurement

Independent sample *t* test provides the significant difference in the various morphometric measurement between two season for *Schizothorax richardsonii* as weight; $t_{(51.133)} = -.092$, $p < .05$, total length; $t_{(33.363)} = -1.564$, $p < .05$, and standard length; $t_{(32.707)} = 1.643$, $p < .05$. It was due to occurrence of seasonal migration. Less number and small size fishes was obtained in January (residential fishes). More number with big in size fishes were got in March as the migration of fish from lower altitude to higher altitude was occurring. Bronmark *et al*., (2013) pointed that fishes migrate to spawn, take seasonal refuge from predators or adverse environmental conditions, or to feed. Similarly, Petr and Swar (2002) found in Sutley river that, *Schizothorax richardsonii* starts upstream migration with the rise in water temperature during March.

Whilst for *Salmo trutta*; $t_{(136.017)} = 1.559$, $p > .05$, total length; $t_{(63.689)} = 2.827$, $p > .05$, and standard length; $t_{(64.959)} = 3.190$, $p > .05$ was not significant between two season. Absence of fish

ladder due to presence of high water fall below the dam construction of THyE restricted the free migration of *Salmo trutta*. Such physical barrier has led to similar results between two seasons without significant in their morphometric measurements.

Distribution of Schizothorax richardsonii

It is observed that *Schizothorax richardsonii* preferred confluence than other habitats. Confluence consists of high volume of water and pool like habitat. Chances of food availability could be more as the confluence comprises of two different streams, which can host various organism. Petr and Swar (2002) points that, in winter season when the water level is low and transparent, *Schizothorax richardsonii* are found in the habitats were maximum volume of water is present. It is mainly to have a shelter. Further, *Schizothorax richardsonii* being a column and benthic feeder, their preference to the confluence could be high as the water volume in confluence has higher and deeper similar to pool.

Distribution of Salmo trutta

Unlike *Schizothorax richardsonii*, *Salmo trutta* was observed preferring run habitat than other habitats. Run habitats consist of wide width, shallow depth, and low current and direct sunlight. The main reason for *Salmo trutta* to prefer run habitat could be because of its evolution on feeding habitat. As the Salmon trutta is a drift feeding fish, the potential of getting food is in run habitat, where the upper surface of river is visible.

Suggestion

A long term study with larger sampling intensity is suggested to really determine the relation between habitat types and environmental factors, which ultimately influences the distribution of fish. Moreover, incorporation of more factors such as presence of substrate and percent rock covers can really determine fish distribution in various habitat types.

Presence of exotic brown trout (*Salmo trutta*) is a common concern among many fish biologists and ecologists in the country. Nevertheless, no single biologist or ecologist has studied on the biology, behaviors such as adaptation, migration, reproduction, and invasiveness in Bhutan. Therefore, the need to study about afore mentioned is suggested. Presence of *Creteuchiloglanis* sp, which is not recorded so far in Bhutan, needs to study thoroughly. Its conformation till species level is first priority for the researchers.

Reference

Baran, E., Jantunen,T. & Chong, C.K.(2007). *Values of inland fisheries in the mekong river basin.* WorldFish Center: Phnom Penh

Bronmark, C., Hulthen, K., Nilsson, P.A., Skov, C., Hansson, L.A., Brodersen, J. & Chapman, B.B. (2013). There and back again: migration in freshwater fishes. *Canadian Journal of Zoology*. 92(6):467-479. doi: 10.1139/cjz-2012-0277

Burrill, A. (2014). Brown trout; and their ecological impacts as an invasive species. <http://depts.washington.edu/oldenlab/wordpress/wp-content/uploads/2015/09/ Salmo_ trutta_bur. Accessed on 6/04/2016

Dema, K. (2007). New fish species discovered in Lingshi. *Kuensel,* Thimphu: Kuensel Corporation

Dubey, G.P. (1978). Survey of the waters of Bhutan physiography and fisheries potential. FAO, Rome

Environment and Social Impact Assessment of Nika Chhu Hydropower Project (2014). Thimphu: Bhutan

FAO (2014). The State of World Fisheries and Aquaculture. FAO, Rome.

Fourth state of nation report (2012). Thimphu: Bhutan

Gurung, D.B. & Thoni, R.J. (2015). *Fishes of Bhutan: A preliminary checklist*. CRDS: College of Natural Resources

Hauer, F.R. & Hill, W.R. (2006). Temperature, light, and oxygen. In Methods in stream ecology, eds. Hauer, F.R. & Lamberti, G.A. 2nd edn., pp.103-117. China: Elsevier

Holmlund, C.M & Hammer, M. (1999). Ecosystem services generated by fish populations. *Ecological Economics* (29): 253–268

IUCN. (2015). *Importance's of freshwater fishes.*<http://*www.iucnffsg.org/Freshwater fishes/importance-of-freshwater-fishes*> *on 2nd Jan 2016*

Kerkhoff, A.J. (2010). Measuring biodiversity of ecology communities. *Ecology Lab*, Biology 229

McClelland, J. (1839). Indian Cyprinidae. *Asiatic Researches (Bishop's College Press, Calcutta)* 19: 217–471

NEC (2011). *Biodiversity*. Thimphu:National Environment Commission

Petr,T. (1999). Cold water and fisheries in Bhutan; Report. Rome, FAO

Petr,T. & Swar, S.B. (2002). Cold water fishes of the Trans-Himalayan Region: Bhutan. FAO Report. Rome

Shrestha, J., Singh, D.M & Saund, T.B. (2009). Fish diversity of tamor river and its major tributaries of eastern himalayan region of nepal. *Nepal Journal of Science and Technology*. 10(2009): 219 – 223

Thoni, R.J. & Hart, R. (2015). Repatriating a lost name: notes on McClelland and Griffith's Cobitis boutanensis (Cypriniformes: Nemacheilidae). *Zootaxa*. 3999 (2): 291–294

Tshering, U. (2011). *Fish diversity and Macro-invertebrates assessment in Punatshang Chhu.* Bsc. thesis, College of Natural Resources, Lobeysa

Tshering, U.(2014). Researchers discover a new fish species endemic to Bhutan. *Information and Communication Service.* <http://www.moaf.gov.bt>

Wangda, P. & Ohsawa, M. (2002). *Transition of forest structure and environmental conditions along the altitudinal gradient in a dry valley*. Upper Lobesa, Bhutan: Thimphu

Annexure

Annexure I: Taxonomic classification of fish found in Nika Chhu

Salmo trutta Linnaeus, 1758

Order: Salmoniformes

Family: Salmonidae

Genus: *Salmo*

Species: *trutta*

Common names: Brown trout, German brown. Sea trout, loch leven trout

Schizothorax richardsonii (Gray 1832)

Order: Cypriniformes

Family: Cyprinidae

Genus: *Schizothorax*

Species: *richardsonii*

Common name: Snow trout, spotted trout, asaila, butte asala, dhumke asala, yul nya, thing nya

Creteuchiloglanis sp Zhou, Li and Thomson, 2011

Order: Siluriformes

Family: Sisoridae

Genus: *Creteuchiloglanis*

Annexure II A. Sampling locations in lower stream

Plot no	Locality	N	E	Altitude
1	Mangdi Chhu confluence	27°26'01.5"	90°27'48.7"	1405m
2	Above M C	27°26'03.4"	90°27'39.9"	1420m
3	Above MC	27°26'09.0"	90°27'21.5"	1462m
4	Above MC	27°26'21.1"	90°27'13.2"	1489m
5	Below old bridge	27°26'28.9"	90°27'01.4"	1493m
6	Below old bridge	27°26'34.2"	90°26'53.1"	1515m
7	Below old bridge	27°26'38.9"	90°26'32.7"	1534m
8	Below old bridge	27°26'42.3"	90°26'21.0"	1539m
9	Old bridge	27°26'48.1"	90°26'21.0"	1579m
10	Above old bridge	27°26'53.6"	90°25'43.3"	1583m
11	Above old bridge	27°26'58.1"	90°25'31.4"	1610m
12	Above old bridge	27°26'60.2"	90°25'19.2"	1618m
13	Below new bridge	27°26'67.9"	90°25'09.0"	1649m
14	Below new bridge	27°26'75.6"	90°24'56.1"	1676m
15	Below new bridge	27°26'79.9"	90°24'44.6"	1691m
16	New bridge	27°26'84.2"	90°24'24.2"	1704m
17	Above new bridge	27°26'89.9"	90°24'16.3"	1721m
18	Above new bridge	27°26'92.3"	90°24'05.9"	1728m
19	Above new bridge	27°26'96.6"	90°23'56.2"	1753m
20	Above new bridge	27°26'97.4"	90°23'31.6"	1779m
21	Above new bridge	27°26'98.2"	90°23'19.2"	1802m
22	Above new bridge	27°26'98.9"	90°23'06.9"	1823m
23	Below Tsheringma	27°26'99.1"	90°22'30.5"	1835m
24	Tsheringma DrupChhu	27°26'99.7"	90°22'29.4"	1852m

Annexure II B. Sampling locations in Upper stream

Plot no	Locality	N	E	Altitude
1	Below dam site	27°27'03.9"	90°22'06.7"	2234m
2	Below Yala	27°27'12.8"	90°21'59.5"	2286m
3	Yala	27°27'16.0"	90°21'57.2"	2322m
4	Below Drangla	27°27'23.6"	90°21'47.8"	2324m
5	Drangla	27°27'35.7"	90°21'30.9"	2393m
6	Drangla	27°27'41.2"	90°21'21.5"	2424m
7	Drangla	27°27'51.2"	90°21'16.0"	2343m
8	Chendepji	27°28'00.9"	90°21'13.4"	2406m
9	Chendepji	27°28'09.1"	90°21'07.9"	2397m
10	Chendepji	27°28'19.7"	90°21'04.7"	2417m
11	Chendepji Chorten	27°28'22.3"	90°20'59.9"	2399m
12	Above Chendepji chorten	27°28'31.0"	90°20'54.2"	2403m
13	Near FMU Chendepji	27°28'47.4"	90°20'44.4"	2431m
14	Below Pasture land	27°28'57.3"	90°20'32.6"	2439m
15	Below Chendepji Bridge	27°29'09.2"	90°20'25.6"	2457m
16	Above Chendepji Bridge	27°29'14.8"	90°19'54.7"	2472m
17	Below Chhuserbu	27°29'19.4"	90°19'49.0"	2505m
18	Below Chhuserbu	27°29'29.0"	90°19'17.7"	2372m
19	Chhuserbu	27°29'53.6"	90°18'48.5"	2507m
20	Above Chhuserbu	27°30'23.4"	90°18'10.9"	2567m
21	Above Chhuserbu	27°30'.32.3"	90°17'52.3"	2583m
22	Above Chhuserbu	27°30'.49.0"	90°17'25.6"	2596m
23	Above Chhuserbu	27°30'.53.6"	90°17'09.2"	2610m
24	Above Chhuserbu	27°31'.08.2"	90°16'58.7"	2631m

Annexure III: Images of different methods used for the study

Fisher man throwing cast net below Drangla.

Cast net throwing below forest FMU office at Chendepji

Mild electric shocking at Chhuserbu confluence

Diverting the tributary that joins Nika Chhu near Chendepji Chorten

SECTION IV: MACRO-INVERTEBRATES

Abstract

This section of report shows the findings and observation about macro-invertebrates. Study was conducted from January to early April, 2016. Kick net method were used during the field survey. A total of seven orders, comprising 17 families with 1338 individuals were recorded during entire period of study. Finding reveals that Ephemeroptera covers the higest portion with representing 32.51% of the total sampling effort. Tricladida was the lowest order repsesenting only 3.36% of sampling effort. In family level, the higest abundance was recorded as *Hydropsychidae* under Tricoptera with 230 individuals. Lowest family recored in the study was *Ceratopogonidae* under Diptera order with 9 individuals. Whilst investigating the habitat preference of macro-inverbrates (Confluence, Cascade, and Run), Cascade with 468 individuals was highest prefered. Followed by Run with 373 individuals and the least was Pool with 343 individuals. Shannon diversity index (*H'*) was calculated to determine the diversity index among various habitat types. Significant difference was not found among the habitat types with Cascade (*H*' = 2.43), Confluence (*H'* = 2.32) and Run (*H'* = 2.01). It is found that water quality of Nika Chhu was (HKH bio score = 6.65), which indicate the good quality of water as per the classification of HKH bio score.

Key words: Abundance, Cascade, *Ceratopogonidae*, Diversity, HKH bio score, *Hydropsychidae,* and Run

Historical Background on studies of Macro-invertebrates in Bhutan

Globally, the scientific knowledge on Macro-invertebrates (Benthic invertebrates) has been accumulated since century back. Many developed countries having sound scientific communities have studied on macro-invertebrates. Bhutan has lately adopted the study on macro-invertebrates. It was in 2004-2007, when the needs of HKH Biotic score for the assessment of lentic and lotic water bodies within Hindu Kush Himalayan region were recognised. As based on WWF – 200 eco-regions, Bhutan was included to conduct an assessment for HKH Biotic score including five other countries. That was the initial study conducted in the soil of our country for macro-invertebrates. National Environment Commission took the role to represent macro-invertebrates of country for HKH Biotic score. Assess-HKH (2007) reported of 41 samples from the country, of which 17 sites were sampled in the post-monsoon period and 24 sites in the pre-monsoon period.

Since then, many ecologist, limnologist and researchers have conducted Macro-invertebrates study within the country. Malicky *et al.* (2008) listed 166 species of caddisflies within a short span of three weeks. In 2009, Uygen Wangchuck Institute for Conservation and Environment (UWICE) published a book tittle "Wildlife Research Techniques in Rugged Mountainous Asian Landscapes" included a chapter "Priorities and Protocols for freshwater monitoring", which was a good signal for many researchers to put interest on it. Following, Dorji (2011) conducted a study on "diversity assessment of macro-inveretbrates in Teobrongchhu stream", recording 20 species of macro-invertebrates belonging to 13 different Orders. Wangchuck and Eby (2013) studied "Aquatic Biodiversity Assessment-*A Pilot Study in Bumthang, Bhutan".* ESIA (2014) of Nika Chhu recorded six orders of macro-invertebrates as Diptera, Ephemeroptera, Megaloptera, Odonata, Plecoptera and Tricoptera from the same study area. A similar study was conducted by Wangchuk (2014) under Jigme Dorji Wangchuck National Park. Dorji (2015) published a New distribution records of *Epiophlebia laidlawi* Tillyard, 1921 (Insecta: Odonata) in Bhutan.

Importance of Macro-invertebrates

Biological Indicator for Lentic and Lotic water bodies

Macro-invertebrates are commonly found in and around water bodies. It is because; water bodies serve as habitat from the breeding until they complete the stage of larvae. Macro-invertebrates have been used as a main biological indicator for determining the quality of water bodies throughout the global (Shah and Shah, 2009). It is used as biological indicator as most of them

live in the water over a longer period. Their unique characteristic such as sensitive for pollution and change in water quality, relatively lower mobility, presence of gills outside of body, linkage between aquatic and terrestrial ecosystem makes easier to abstract valuable information about water body according to the needs of our objectives. Researchers throughout the globe acquire lots of information such as effects of non-point and point pollution – nutrient content, toxic pollution and changes in geo-physical conditions of water bodies (Gurung, 2013). Similar like other part of globe, Assess-HKH (2007) has completed in making a HKH Bios score for HKH region. The main objective was to rank the macro-invertebrates according to its tolerance level. It is reported that, different species have different level of adaptation with disturbance and pollution.

Roles in aquatic food webs

Macro-invertebrates play a critical role in an aquatic food web which results in maintaining the aquatic ecosystem stable. They play both roles of predator as well prey. Wangchuk and Eby (2013) stated that they consume the algae and other organic matter which help to control nutrients and therefore influences water quality (e.g., eutrophication). They are a key component of the food web by providing a wide range of food sources for predators including larval and juvenile life stages of every fish species, small adult fish, as well as terrestrial animals like birds and bats.

Materials used for studying Macro-invertebrates

Kick net was used for collection of sample from the river. Bucket was used for collecting the specimen from net. Forceps was deployed for picking specimen and sorting into major groups. Pet disc was used to collect the grouped specimen. Key to identification of macro-invertebrates by Subodh Sharma, Aquatic Biodiversity Assessment - *A Pilot Study in Bumthang, Bhutan* by Wangchuk and Eby, and other various books and papers were used in field for spot identification. 10 ml container was used to transport the samples for further identification at College of Natural Resources

Methods used for Macro-invertebrates

The macro-invertebrates were sampled in different location along the streams in January 2016 and in March – April 2016 (table 6).

Table 6. Details of plot locations

Plot #	Location	Habitat	Altitude	N	E
1	Mangdechu confluence (MC)	Confluence	1405m	27°26'01.5"	90°27'48.7"
2	Above MC	Cascade	1462m	27°26'09.0"	90°27'21.5"
4	Below old bridge	Run	1534m	27°26'38.9"	90°26'32.7"
5	Old bridge	Confluence	1579m	27°26'48.1"	90°26'21.0"
6	Above old bridge	Cascade	1618m	27°26'60.2"	90°25'19.2"
7	New bridge	Confluence	1704m	27°26'84.2"	90°24'24.2"
8	Above new bridge	Cascade	1753m	27°26'96.6"	90°23'56.2"
9	Below Tsheringma	Run	1835m	27°26'99.1"	90°22'30.5"
10	Tsheringma Drupchu	Confluence	1852m	27°26'99.7"	90°22'29.4"
11	Yala	Run	2322m	27°27'16.0"	90°21'57.2"
12	Drangla	Confluence	2424m	27°27'41.2"	90°21'21.5"
13	Chendepji Chorten	Confluence	2399m	27°28'22.3"	90°20'59.9"
14	Above Chendepji chorten	Cascade	2403m	27°28'31.0"	90°20'54.2"
15	Above Chendepji Bridge	Run	2472m	27°29'14.8"	90°19'54.7"
16	Below Chuserbu	Cascade	2505m	27°29'19.4"	90°19'49.0"
17	Above Chuserbu	Cascade	2505m	27°29'19.4"	90°19'49.0"
18	Chuserbu	Confluence	2507m	27°29'53.6"	90°18'48.5"
19	Above chuserbu	Pool	2567m	27°30'23.4"	90°18'10.9"
20	Above chuserbu	Run	2583m	27°30'.32.3"	90°17'52.3"

Kick net of a square shape with 0.5m x 0.5m and 500µm mesh size was used for collection of macro-invertebrates. Plots were laid at every 500 metres. The total plots laid in the entire study area was 20 numbers. The details of habitat such as run/confluence/cascade with altitude, name of location were recorded. Five minute kick-and-sweep sampling method was done using the net by placing across the water course in the stream with the lower ends of the net held by stones/hand placed over its edges. An area of $1m^2$ upstream was disturbed manually (turning and moving the stones in the stream scrubbing them with hands) for couple of minutes. Then the net was removed from the stream with a forward scooping motion to prevent from loss of the species. All debris and organisms were handpicked from the net. The same procedures were repeated for the collection of the other sample to have consistency while collecting samples. The specimens were stored in 10 percent formaldehyde solution and taken to the Laboratory at College of Natural Resources, where they were sorted and identified with the help of Hindu Kush Himalaya identification key. After being identified, each specimen were conserved in 70% alcohol and deposited in the Laboratory.

Results

Composition of Macro-invertebrates in Nika Chhu

Order wise

During the entire period of survey, the study recorded seven orders of macro-invertebrates comprising of 17 families with 1338 individuals. The seven order are Coleoptera (Burmeister, 1839) commonly known as "Beetles", Diptera (Linnaeus, 1758), common name as "True flies", Ephemeroptera (Hyatt and Arms, 1891) commonly referred as "May flies", Odonata (Fabricius, 1793) commonly called as "Dragon flies" and "Damsel flies", Plecoptera (Burmeister, 1839), also called as "Stone flies", Tricladida (Lang, 1884), commonly known as "Flat worms" and Tricoptera (Kirby, 1813) which is also called as "Caddis fly". As shown in Figure 9, the order Ephemeroptera represents the maximum with 32.51% (*n* = 435), followed by Tricoptera with 25.56% (*n* = 342), Diptera by 15.47% (*n* = 207), Coleoptera by 12.78 (*n* = 171), Plecoptera by 7.03% (*n* = 94), Tricoptera by 3.36% (*n* = 45), and the lowest was represented by Odonata with 3.29% (*n* = 44).3.0

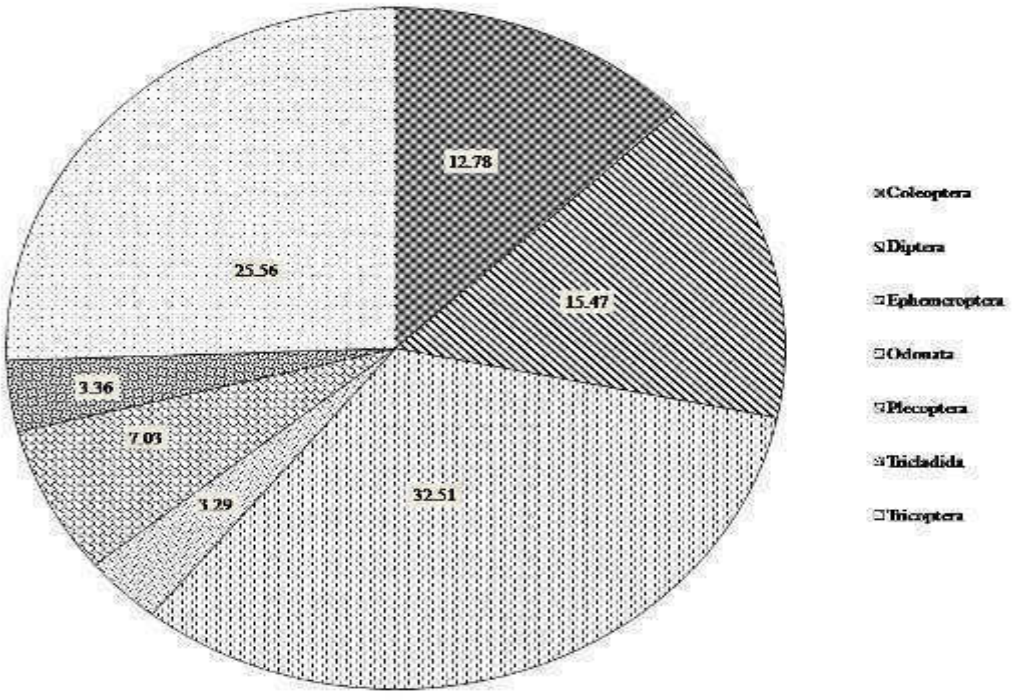


Figure 11. Percentage represented by individual order in Nika Chhu

Family wise

Whilst going by family, as shown in Figure 10. Plecoptera was recorded with two families. *Perlidae* (*n* = 76) and *Perlodidae* (*n* = 18). Tricoptera was represented by *Hydropsychidae*, as highest with n = 230 and Rhyacophilidae with n = 112. Under Ephemeroptera, *Ephemerellidae* (n = 191), *Ephemeridae* (*n* = 138), and *Heptagenidae* (*n* = 106) were recorded. The order Coleoptera was represented by only one family. It was *Scirtidae* with *n* = 171 individuals recorded. Odonata was represented by *Gomphidae* (*n* = 31), and *Epiophlebiidae* (*n* = 13). The order Diptera was represented by six families as *Psychodidae* (*n* = 123), *Limoniidae* (*n* = 32), *Dixidae* (*n* = 12), *Ceratopogonidae* (*n* = 9) with the lowest record, *Similidae* (*n* = 11) and *Tipulidae* (*n* = 20). *Planariidae* (*n* = 45) was only family recorded under Tricladida order.

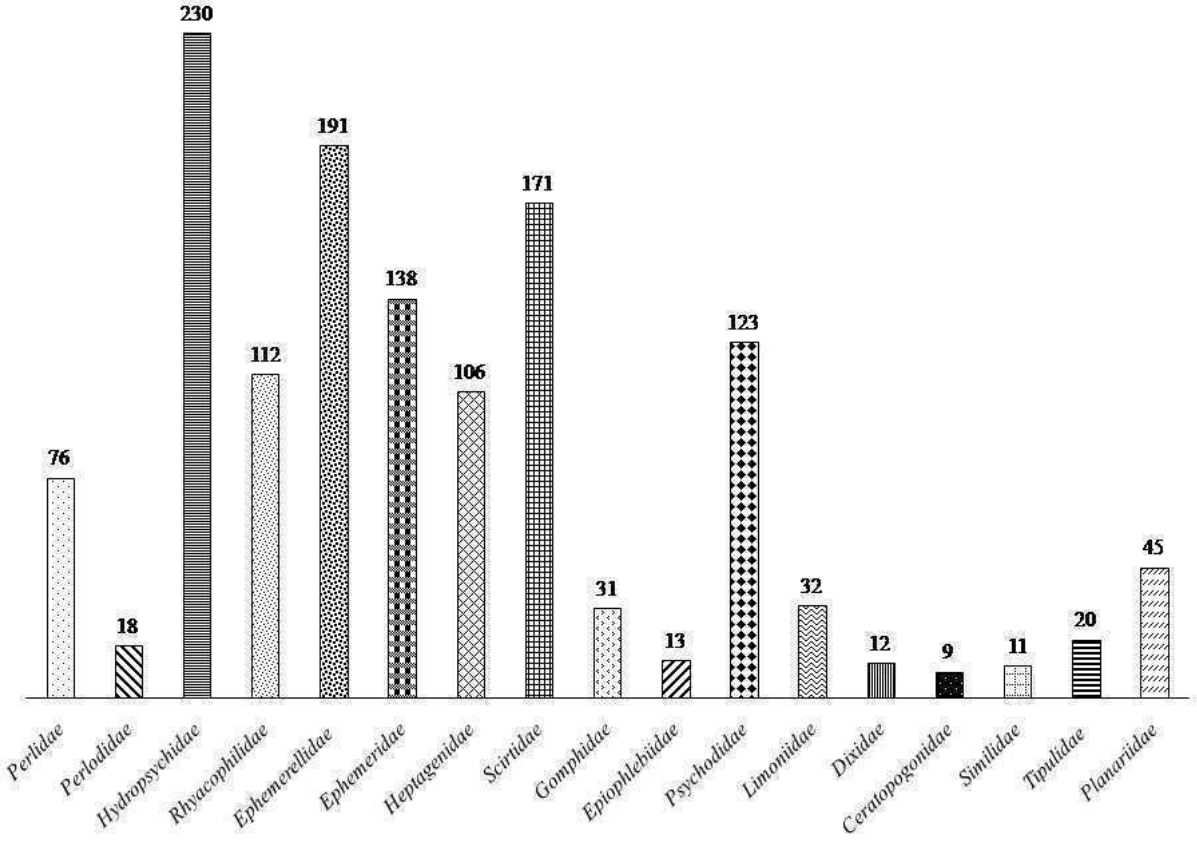


Figure 12. Abundance of family in Nika Chhu

Distribution of Macro-invertebrates in various Habitats

Order wise

To really understand the preference of river habitat by different order and families, river habitat was classified into three habitat types – Confluence: A combination of pool (through volume of water) habitat and riffle (through flow of river) habitat of river, where tributaries joins the main river. Run: Shallow with lesser speed of river running, laminar flowing of river running, having majority of river bed covered by pebbles and gravels. Cascade: Shallow with turbulent style of river flowing, river bed mostly covered by bed rock and boulder. Figure 11 provides clear information that different order has preference of different habitat. Coleoptera (n = 63 ± 64) is observed to prefer cascade and run but least with Confluence. Ephemeroptera (n = 158) and Tricladida (n = 26) on other hand prefer confluence than other two river habitat. Diptera (n = 99) prefers much in cascade compared to other habitats. While Plecoptera (n = 38) and Tricoptera (n = 129) prefers confluence and cascade on almost equal ratio. Odonata (n = 12 ± 13) is observed to have a generalized habitat preference without any specialization on habitat preference

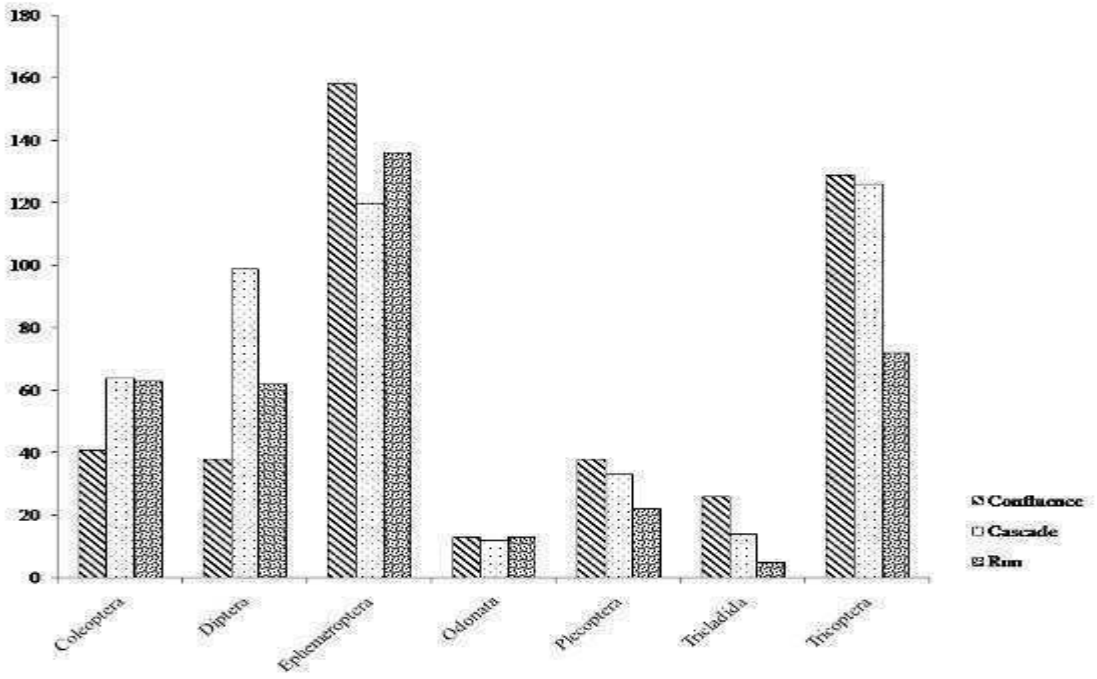


Figure 13. Distribution of macro-invertebrates (order wise) in various river habitats

Family wise

Similarly, the distribution of families in different river habitats was also observed in Figure 12. It is observed that different family has different preference of habitats. Such as *Limoniidae* (n = 19), *Tipulidae* (n = 20), *Ceratopogonidae* (n = 9), *Similidae* (*n* = 11) of Diptera families, *Perlidae* (*n* =30) of Plecoptera, *Hydropsychidae* (*n* = 89) of Tricoptera, and *Gomphidae* (*n* =10) of Odonata prefers the cascade habitat. On other hand, *Ephemerellidae* (*n* = 99) of Ephemeroptera, *Planariidae* (*n* = 26) of Tricladida, *Perlodidae* (*n* = 12) of Plecoptera, *Rhyacophilidae* (*n* = 70) of Tricoptera, *Dixidae* (*n* = 12) of Diptera and *Epiophlebiidae* (*n* = 8) of Odonata prefers Confluence habitats. The remaining families like *Psychodidae* (*n* = 60) of Diptera, *Heptagenidae* (*n* = 47) and *Ephemeridae* (*n* = 67) of Ephemeroptera prefers run habitats.

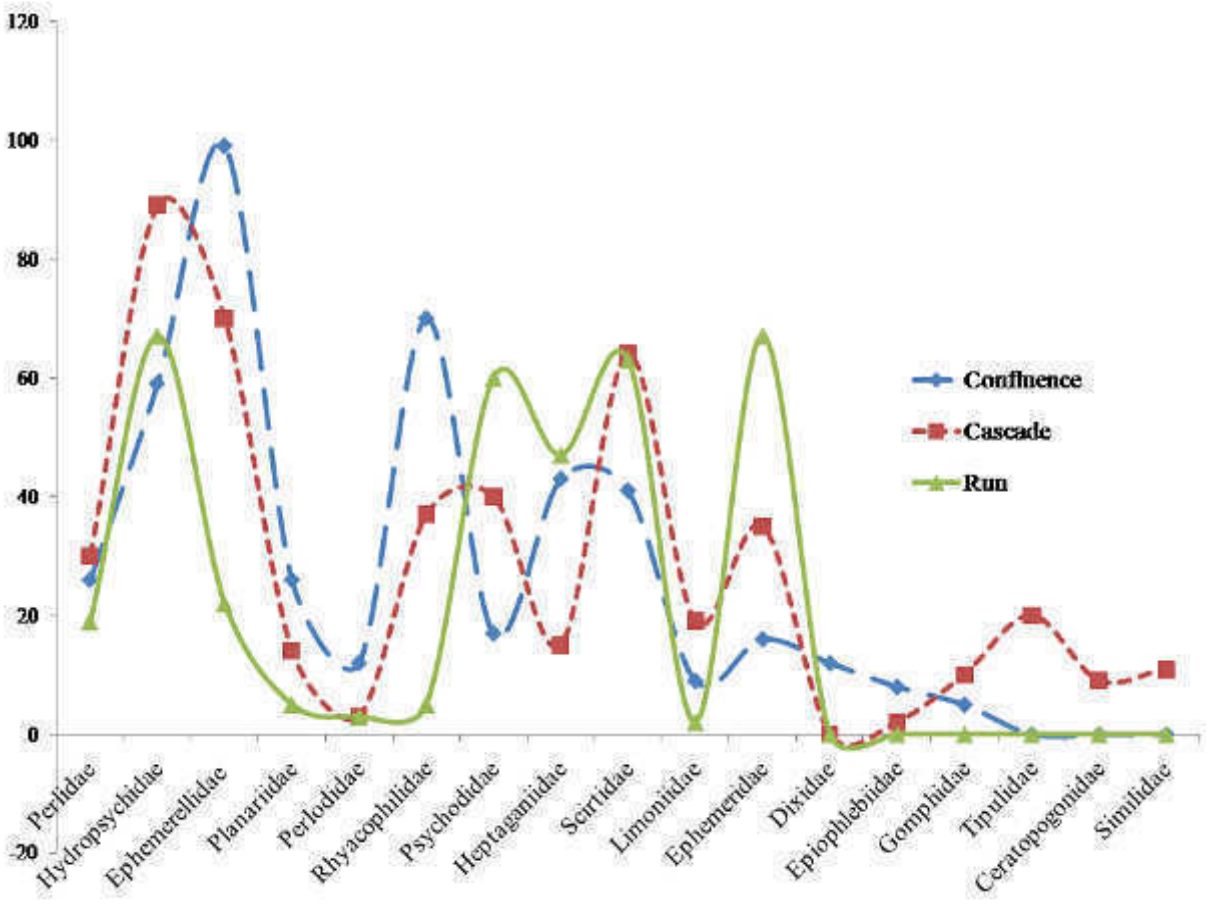


Figure 14. Distribution of macro-invertebrates (Family wise) in various river habitats

Diversity Index of Macro-invertebrates in Nika Chhu

Diversity index (*H*') was calculated by using Shannon Diversity index to determine the diversity in different taxonomical level and various habitats. The *H*' for order is provided as 1.68, Family wise *H*' = 2.44 is almost equal to that of Cascade (*H*'= 2.43). While the *H*' for Confluence is *H*' = 2.32 and Run (*H*' = 2.01) as shown in Figure 13. The detail diversity index (H') for every order and species wise is provided in Annexure II

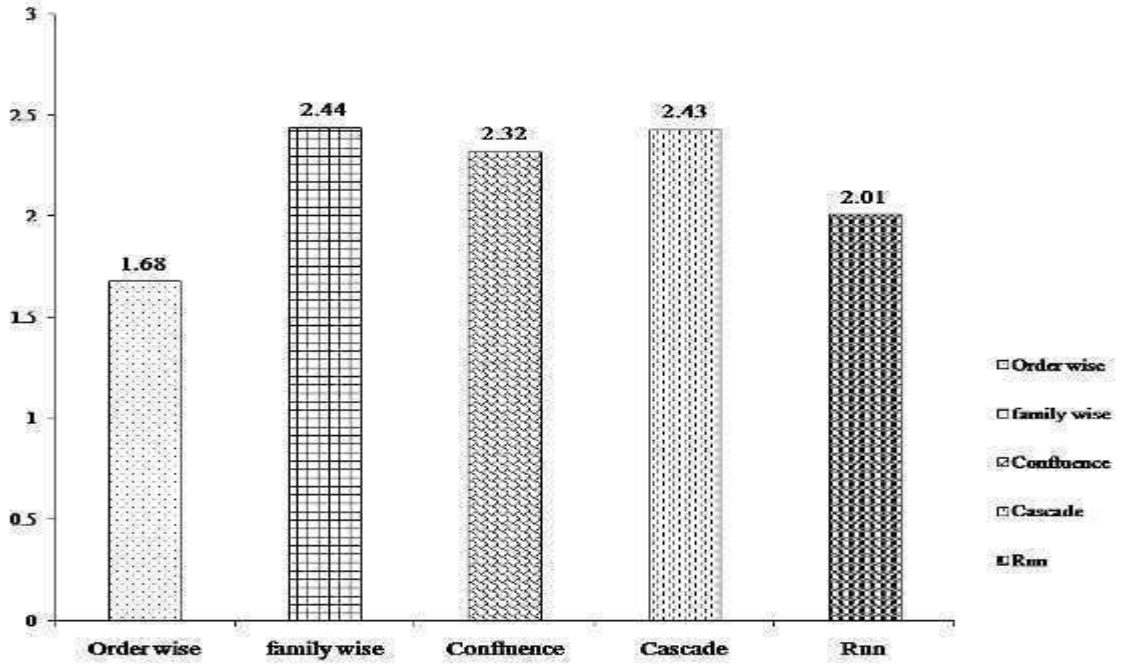


Figure 15. Diversity index of Nika Chhu

HKH Bios Score for water quality

The need of Bios score in Himalayan region has been raised since 1990s, but the consensus has reached only in 2004. It has taken scientific community of Boko University and Kathmandu University for three years to complete the HKH bios score. Ofenbock *et al*. (2010) mentioned that score has been given accordance to the tolerance level of each family to the point and non-point pollution and disturbances (Table 7 and 8). The scores ranges from 1 to 10 with highly tolerance family = 1 and the sensitive family with 10. Accordingly, weight for each family was also given. The basic aim of HKH Bios score was to have a direct determination of water quality through computing the values mathematically. Table 7 Shows the HKH bios score with weight and HKH bios score for communities.

Table 7. Taxon wise family HKH bios score. Source: Hydrobiologia (2010)

Taxon	HKH bios	Weight
Perlidae	8	1
Perlodidae	9	1
Hydropsychidae	7	1
Rhyacophilidae	8	1
Ephemerellidae	7	1
Ephemeridae	8	1
Heptagenidae	8	1
Scirtidae	8	1
Gomphidae	9	2
Epiophlebiidae	10	5
Psychodidae	1	5
Limoniidae	8	1
Dixidae	9	1
Ceratopogonidae	2	1
Similidae	7	1
Tipulidae	7	1
Planariidae	4	1

Table 8. HKH scores for community in eastern Himalayan Broad Leaved eco region. Source: Hydrobiologia (2010)

Class	Boundaries
Reference/good	Upper - 7.7
Good/moderate	Upper - 6.3
Moderate/poor	Upper - 4.6
Poor/bad	Upper - 2.3

With the above provided HKH bios score, while computing the HKH bios score for Nika Chhu as in Figure 14, it is clearly provided that the water quality of Nika Chhu is very good as the all values lies under reference/good in table 8. The overall Nika Chhu HKH bios score class

is 6.65. Run habitat has a maximum HKH bios score with 6.8. Confluence has 6.74 and the Cascade has 6.6. While analyzing the results of HKH bios score, with the different habitats, it shows that Run habitat has good quality of water compared to Confluence and Cascade.

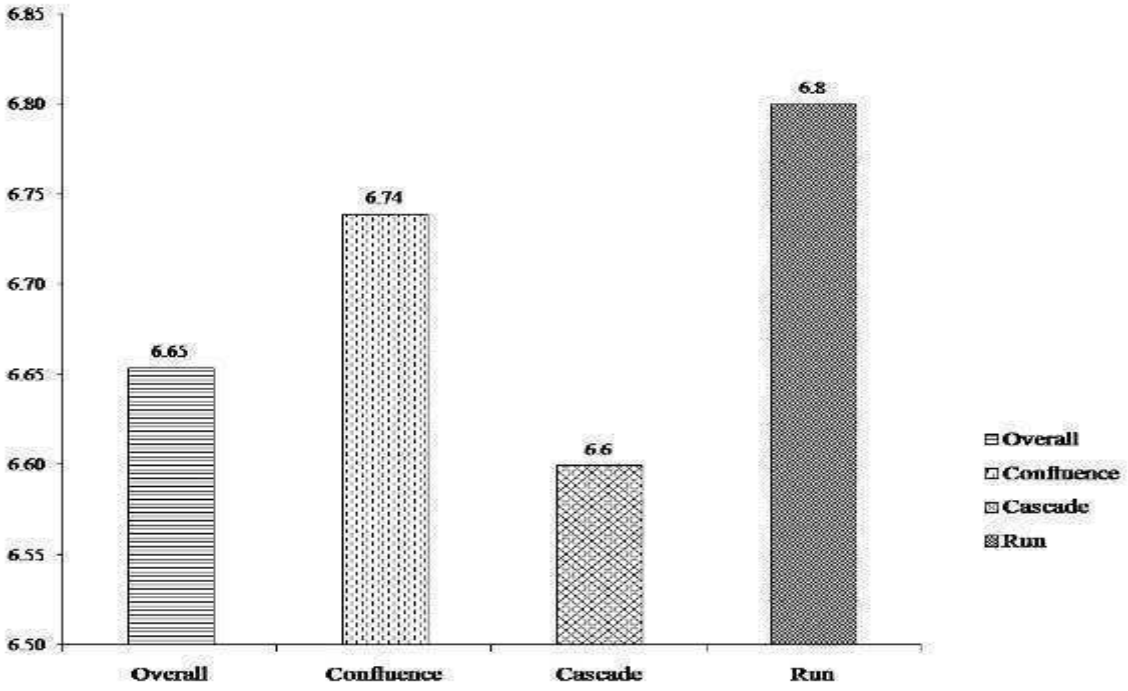


Figure 16. HKH bios score for Nika Chhu

However as there isn't any vast difference in the HKH bios score among the habitats, we have not taken in account of differences in HKH bios score. In general, the HKH bios score clearly indicates that quality of Nika Chhu is still fresh without having major pollution and disturbance.

Discussion

Composition, Abundance and Diversity of Macro-invertebrates

Within short period of time, the study could manage to get 17 families with seven orders. In a global context, BugGuide, (2016); Zhang (2011) reported that, *Scirtidae* family is estimated to have 39 genera, 800 species worldwide. *Psychodidae* consist of 144 genera, 3026 species, *Limoniidae* with 188 genera, 10777 species, *Dixidae* with 9 genera, 200 species, *Ceratopogonidae* with 130 genera, 5902 species, *Similidae* with 35 genera, 2121 species and *Tipulidae* with 40 genera, 4415 species. *Ephemerellidae estimates* with 18 genera, 160 species,

Ephemeridae with 7 genera, 150 species and *Heptagenidae* with 34 genera, 529 species. *Gomphidae estimates* with 90 genera, 900 species and *Epiophlebiidae* with 1 genus, 4 species. *Perlidae* consist with the estimation of 52 genera, more than 1000 species and *Perlodidae* with 30 genera, 103 species. Planariidae comprises of 12 genera with yet to determine the species. *Hydropsychidae is considered to have* 49 genera, 1409 species and Rhyacophilidae with 6 genera, 783 species. Further, ESIA (2014) reported about having Magaloptera order in Nika Chhu. As the season variation in Macro-invertebrates plays a vital role, study in different season could re confirm the presences of other orders and families. When going through the conservation status of each family according to IUCN red list, only the presence of *Epiophlebiidae* is classified as nearly threaten family especially the *Epiophlebiidae ludlawi* Tillyard, 1921 species which present in the Nika Chhu. The presences of *Epiophlebiidae ludlawi* is also reported by Dorji (2015).

Distribution of Macro-invertebrates in various Habitats

Although there is a variation among the abundance of macro-invertebrates distributed in various habitats, this study has observed that, composition of families has a clear difference between three different habitats (Confluence, Cascade and Run). It is observed that the Cascade has highest number of family composition with 16 families out of having 17 in entire study area. Confluence has 14 families and the Run has 12 families. It is clearly mentioned that, often, the composition and diversity of macro-invertebrates are found in riffle type habitats, where the velocity of stream is higher than other habitats, stream bed covered by cobbles and gravels (Gurung, 2013; Wangchuk and Eby, 2013; Ofenbock, 2010). In our study, we have not classified the habitat type into riffle but most of the riffle was included in Cascade and confluence. This could be the reason for obtaining more species composition at cascade followed by Confluence. However, there are some families and order, which prefers other habitat types, therefore, to have inclusiveness of all macro-invertebrates, the study has included other habitat as well.

HKH Bios Score for water quality

It is clearly provided that the water quality of Nika Chhu is very good as all values are in reference/good boundary. In this context, the observation we have done and the result from HKH bios score has a good relation. It is observed that there isn't regular and mass agent of pollution along the Nika Chhu. Nevertheless, minor pollution agents like chemicals leaching from

agriculture field (settlements using chemical fertilizers and pesticides for potato farming), direct waste disposal from the villagers, hotelier, shop keepers and constructors are seen in rampage. It further gives us information that we have to be vigilant and protective to continue keeping the quality of Nika Chhu all times to come.

Suggestion

Nevertheless, the representation of macro-invertebrates of Nika Chhu by this study is a gross under estimation. Many orders and families could be present if we could study the Nika Chhu in different season as well in longer period of time.

The presence of *Epiophlebiidae* is classified as "Nearly threaten" family especially the *Epiophlebiidae ludlawi* Tillyard, 1921 species, which is present in the Nika Chhu. More concern about its conservation strategies has to be taken care. Proper study on its ecology can be short term suggestion to have proper conservation in long term.

It is observed that direct waste disposal from the villagers, hotelier, shop keepers and constructors are seen in rampage. It could add up the risk in maintaining the quality of Nika Chhu in longer run. Therefore, proper mitigation and management of waste has to be taken care by the concern authorities.

Reference

Assess – HKH (2007). Development of an Assessment System to Evaluate the Ecological Status of Rivers in the Hindu Kush-Himalayan Region. Kathmandu: Nepal

BugGuide. www.bugguide.net/node/view/76. Accessed on 02/06/2016

Dorji, Tshering. (2015). New distribution records of *Epiophlebia laidlawi* Tillyard, 1921 (Insecta: Odonata) in Bhutan. *Journal of Threatened Taxa* 7(10): 7668–7675

Environment and Social Impact Assessment of Nika Chhu Hydropower Project (2014). Thimphu: Bhutan

Gurung, P.B (2013*). Macro-invertebrate diversity, Composition, family biotic index, physiochemical parameters in Toeb Rongchhu, its tributaries, and Punatshang Chhu.* Bsc. thesis. College of Natural Resources. Lobeysa

Malicky, H., Karma, G., & Moog, O. (2008). A survey of caddisflies: Insecta, Trichoptera of Bhutan with suggesstion to further future research

Tshering, D. (2011). *Fish diversity and Macro-invertebrates assessment in Punatshangchu Chhu.* Bsc. thesis, College of Natural Resources, Lobeysa

Wangchuk, K. (2015). *Macro-invertebrate diversity and water quality of streams within and outside jigme dorji national park.* Bsc. thesis. College of Natural Resources. Lobeysa

Shah, D. N and Shah, R.D.T (2009). Biological monitoring – a sustainable water management approach. *International Symposium on Environment, Energy and Water in Nepal: Recent Researches and Direction for Future.* Kathmandu, Nepal

Ofenbock, T., Moog, O., Sharma, S and Korte, T (2010). Development of the HKHbios: a new biotic score to assess the river quality in the Hindu Kush-Himalaya. *Hydrobiologia* 651:39–58

Wangchuk, J. & Eby, L., (2013). Aquatic Biodiversity Assessment –A pilot study in Bumthang, Bhutan. Royal Government of Bhutan, UWICE Press, Bumthang

Zhang, Z, Q. (2011). Animal biodiversity: An introduction to higher-level classification and taxonomical richness. Zootaxa 3148: 1-237

Annexure

Annexure I: Procedures for sampling macro-invertebrates below Nika Chhu.

1st procedure : Making ready for kick net sampling for macro-invertebrates

Second procedure: Collected macro-invertebrates taking out of stream

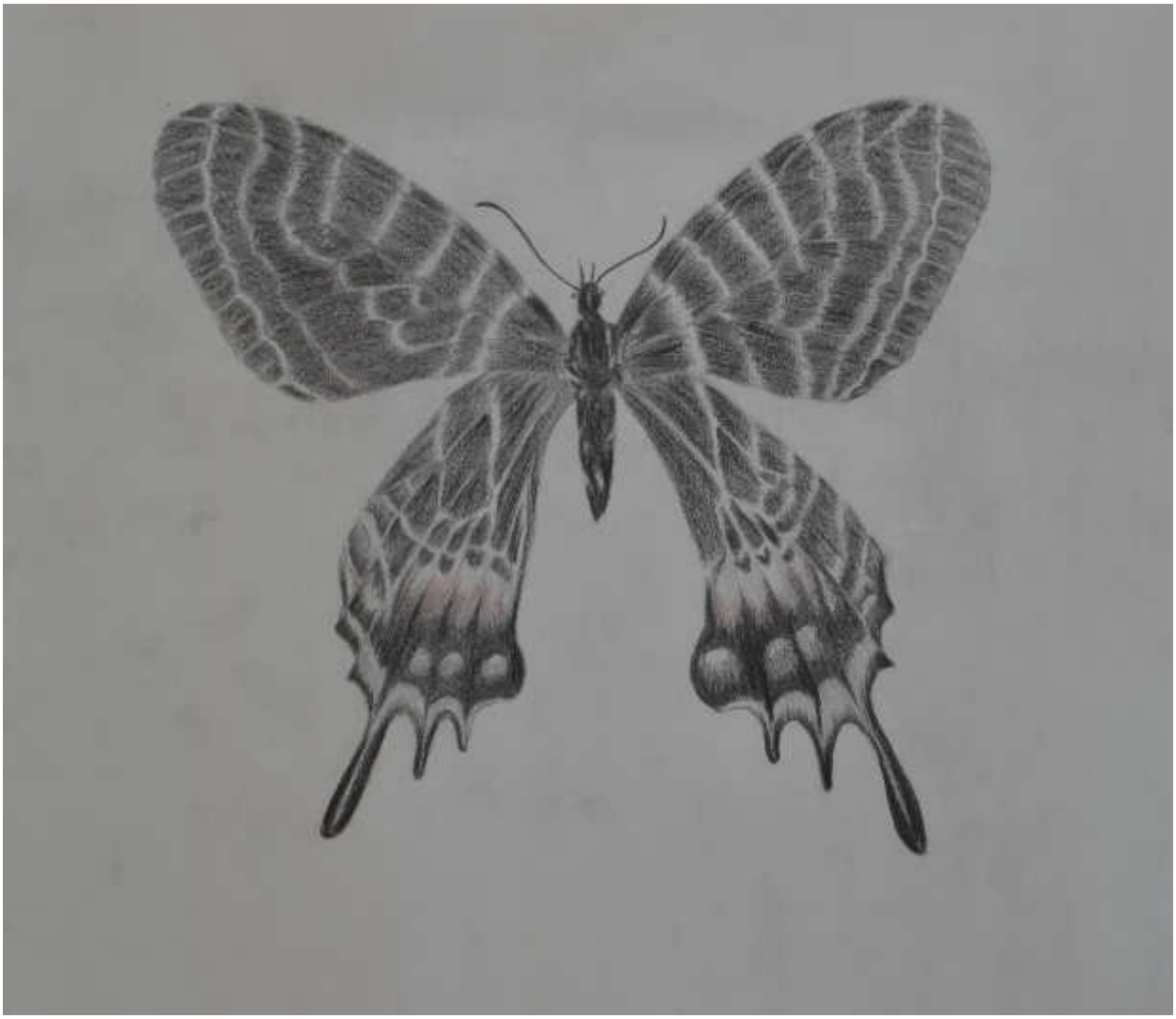
Third procedure: Sorting macro-invertebrates into various order and families

Fourth: Identify with the help of identification keys.

Annexure II: Order wise and Family wise diversity index.

Order	Tally	Pie	H
Coleoptera	171	0.1278	0.263
Diptera	207	0.15471	0.289
Ephemeroptera	435	0.32511	0.365
Odonata	44	0.03288	0.112
Plecoptera	94	0.07025	0.187
Tricladida	45	0.03363	0.114
Tricoptera	342	0.25561	0.349
Total	**1338**		**1.679**

Family	Tally	Pie	H
Perlidae	76	0.0568	0.163
Perlodidae	18	0.01345	0.058
Hydropsychidae	230	0.1719	0.303
Rhyacophilidae	112	0.08371	0.208
Ephemerellidae	191	0.14275	0.278
Ephemeridae	138	0.10314	0.234
Heptagenidae	106	0.07922	0.201
Scirtidae	171	0.1278	0.263
Gomphidae	31	0.02317	0.087
Epiophlebiidae	13	0.00972	0.045
Psychodidae	123	0.09193	0.219
Limoniidae	32	0.02392	0.089
Dixidae	12	0.00897	0.042
Ceratopogonidae	9	0.00673	0.034
Similidae	11	0.00822	0.039
Tipulidae	20	0.01495	0.063
Planariidae	45	0.03363	0.114
Overall	**1338**		**2.44**



***Bhutanitis ludlowi*: The national butterfly of Bhutan**

SECTION V - BUTTERFLIES

Abstract

This section of report comprises findings about Butterflies along Nika Chhu. Due to seasonal fluctuation and migration of butterflies, the study was conducted from late March to early April, 2016. To detemine the diversity and distribution, opportunistic visual encounter and capturing - random search, catching and collection of butterflies with the help of Sweep net method were used during the field survey. Occasionally, modified brait trap of Oulu was also used. A total of 11 species with four family (*Pieridae* (Swainson, 1820), *Lycaenidae* (Leach, 1815), *Nymphalidae* (Rafinesque, 1815) *and Papillionidae* (Latreille, 1802), was studied during entire period of study. *Nymphalidae* (45.24%) represents the most abundance in the area and *Papillionidae* as a least abundance with 11.82%. Highest individuals was recorded with *Venessa Indica* Herbst, 1794, (A = 58, *H'*= 0.298, 16.62%) and the lowest was *Mycalensis francisca* Stoll, 1780, (A = 14, *H'* = 0.129, 4.01%). While the distrubution of Butterflies in upper stream and Lower stream was also investigated. In the lower stream, it was found that three family with *Nymphalidae* (53.72%, n = 130), *Lycaenidae* (29.34%, *n* = 71), *and Papillionidae* (16.94%, *n* = 41), were present. Similarly, in upper stream, three family with *Pieridae* (66.28%, *n* = 57), *Lycaenidae* (24.42%, *n* = 21), *Nymphalidae* (9.30%, *n* = 8) were present. Shannon diversity index (*H'*) for the lower stream was (*H*' = 2.017) and upper stream has (*H*' = 1.334).The diversity index of butterflies for Nika Chhu was *H*' = 2.039.

Key words: Abundance, Distribution, *Lycaenidae*, *Nymphalidae,* Opportunistic visual encounter, *Papillionidae, Pieridae*

Historical Background on studies of Butterflies in Bhutan

History reminds about the studies on butterflies being conducted by several individuals. It was English naturalist Frank Ludlow and George Sheriff in 1933, 12th August who conducted the studies for the first. Latter the species described by the aforementioned naturalist was confirmed as new species by Gabriel. A.G in 1942. Thereafter, paucity in the studies of butterfly remained for several decades. It was when Van der Poel and Wangchuk (2007) studied and recorded 136 species in their publication "Butterflies of Bhutan". Then, Wangdi *et al.,* (2012) recorded 186 species belonging to Nymphalids family, 42 species of Swallowtails belonging to *Papillionidae* family and 93 Hesperid. Nidup *et al.* (2014) carried out similar study at Royal National Manas Park, where author recorded 181 species of butterflies. Dorji (2014) recorded 80 species of butterflies in and around the Phobjikha Valley. Singh (2014) at Mendregang geog under Tsirang Dzongkhag has recorded a total of 586 species of butterflies belonging to 78 genera representing five families (*Papillionidae, Pieridae, Lycaenidae, Nymphalidae* and *Hesperiidae* Latreille, 1809), which is highest record as of now in country.

Roles of Butterflies

Ecological roles

Butterflies are one of the most group in invertebrates that has been widely studied globally. It is one of the group having described till the species level. With its diurnal and attractive colouration makes them easily notice in any kind of habitat. Butterflies are one of important components of biodiversity and it plays a vital role in ecosystem. Their role in food web is crucial for the biodiversity to exsist. Tiple (2012) mentioned that butterflies are considered as food source for many arthropods, birds, reptiles and small mammals. They further plays an ideal role in shaping the forest dynamics. Leps and Spitzer (1990) reported the role of butterflies in pollinating the flowering plants has shown a symbiotic relationship with plants diversity. It is mainly due to their dependence on plants for larval food. In the region of advance scientific knowledge, butterflies are already used as one of good biological indicators for determing the environmental quality. It is used as biological indicator as Leps and Spitzer (1990) asserted that butterflies are sensitive to the disturbance of habitat and climate changes, their vastness in range of habitat from broad habitat to a small micro-habitats.

Economical roles

Despite ecological benefits of butterflies, they have an economical values as well. In brief, Singh (2011) conceptualized the example of economic benefits such as in USA and Australia; butterflies are reared purposely in large numbered to release them to mark the important occasions. Butterfly rich areas in many nations are designated as garden, parks, and trails for ecotourism. Holding great aesthetic value and good signs for many communities, the ecotourism are functioning in great height. Similarly, in national context, it is a here say that many Japanese tourist visit Trashiyangtsi simply to see the *Bhutanitis ludlawi*, which could have a similar fate of ecotourism in the country in near future.

Materials used for studying Butterflies

Sweep net was main equipment that has been deployed in entire period of studies. In addition, honey, sugary food items are also used during the study. Buckets were deployed to make a simple and modified brait trap - Oulu trap of Laaksonen *et al*., 2010. For species identification, several books and keys for butterflies such as Butterflies of India (Singh, 2011), Butterflies of Bhutan: Mountains, Hills and Valleys between 800 – 3000 m (Van der Poel, and Wangchuk, 2007), and Butterflies in and around Phobjikha valley (Dorji, 2014), were used.

Methods used for Butterflies

Opportunistic visual encounter and capturing - random search, catching and collection of butterflies along the stretch of Nika Chhu was main method adopted while conducting the studies. Similar methods were used by many ecologists for the studies such as by Dorji (2014). Field survey was carried out during 0900 to 1200 in the morning and 1400 to 1600 in the afternoon during the sunny days because butterfly usually becomes active (Sundufu & Dumbuya, 2008; Ramesh *et al*., 2010). Due to high altitude and ecological consequences of Butterflies, Study on butterflies along Nika Chhu was conducted only once, that is in late March – early April during the entire study period. Capture-photo-release method has been carried out in the entire survey period. Specimens were held temporarily for digital photo documentation, and then promptly released. Photograph ID numbers were recorded in the format. Butterflies were photographed from different angles as much as possible to obtain sufficient photographs to enable positive identification of species.

Results

Lower stream of Nika Chhu

Family dominancy

As mentioned earlier in methodologies, the report consist of result in two different stream zones (Lower and Upper stream). Of having four families in overall study area, the lower stream comprises of 3 families. *Nymphalidae, Lycaenidae* and *Papillionidae* were 3 families that are present in the lower stream of Nika Chhu. With 3 families, the lower stream represents 8 genera and 8 species out of 11 genera and 11 species overall (Figure 15). This 8 species were *Chiliria kina* (Blue Tit) *Helio phorous moorei* (Azure sapphire), *Letha verma* (Straight banded tree brown), *Melanitis leda* (Common Evening Brown), *Mycalesis francisca* (Himalayan Lilacine Bushbrown), *Neptis hylas (*Common Sailer), *Papilio bianor ganesa* (Common Peacock), and *Venessa indica* (Indian Admiral).

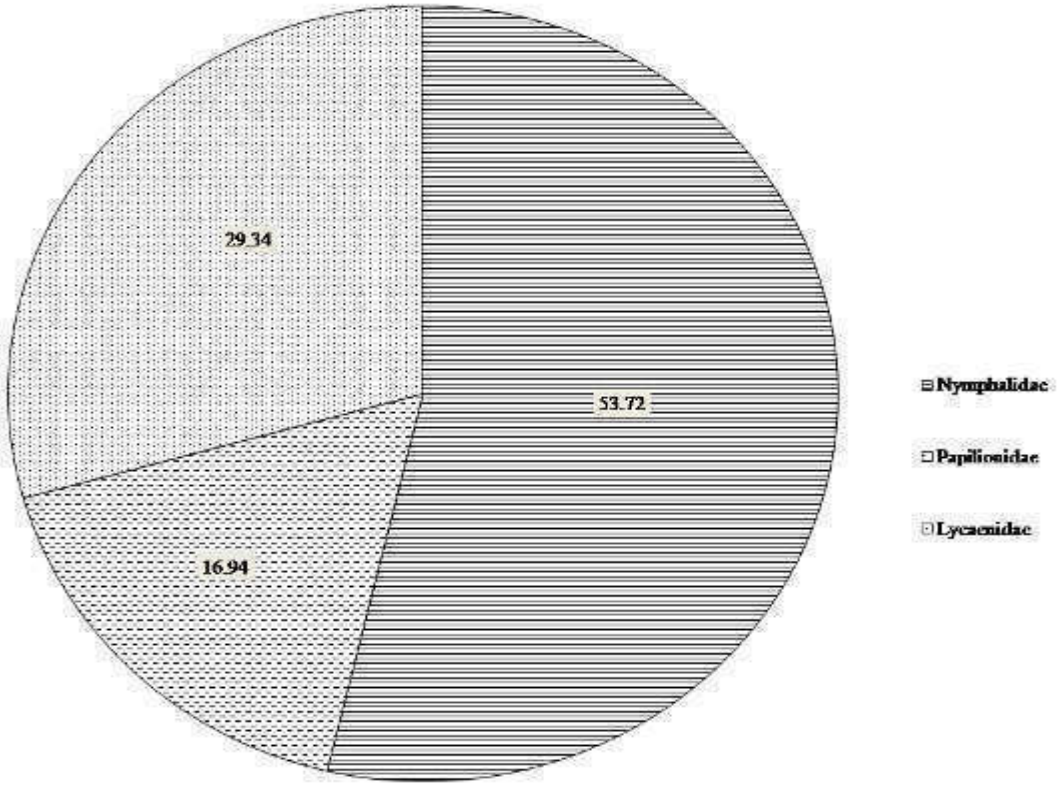


Figure 17. Order wise dominancy in lower stream

Out of 157 individuals under *Nymphalidae* family in entire study area, 130 individuals are reported from the lower stream representing 53.72% of butterflies in lower stream. It was then followed by *Lycaenidae*, where 71 out of 92 individuals are reported from lower stream, covering 29.34%, of butterflies in lower stream. The least was recorded with *Papillionidae*, of which the entire individuals (n = 41) are recorded from lower stream representing 16.94% of butterflies in lower stream as shown in Figure 15.

Species abundance and diversity index

The lower stream has recorded 11 species under 3 families. In the lower stream, 242 individuals of butterfly were recorded. Within the 11 species and 242 individuals, the occurrence and abundance of individuals are observed differently. Similarly, the overall diversity index for the lower stream is (H' = 2.017). Followings are the results arranged from the highest abundance and diversity index to the lowest one. *Helio phorous moorei* (A = 44, H' = 0.310, 18.18%), *Papilio bianor ganesa* (A = 41, H' = 0.301, 16.94%), *Letha verma* (A = 36, H' = 0.283, 14.88%), *Neptis hylas (*A = 35, H' = 0.280, 14.46%), *Venessa indica* (A = 29, H' = 0.254, 11.98%), *Chiliria kina* (A = 27, H' = 0.245, 11.16%), *Melanitis leda* (A = 16, H' = 0.180, 6.61%) and *Mycalesis francisca* (A = 14, H' = 0.165, 5.79%) as shown in Figure 16 and 17.

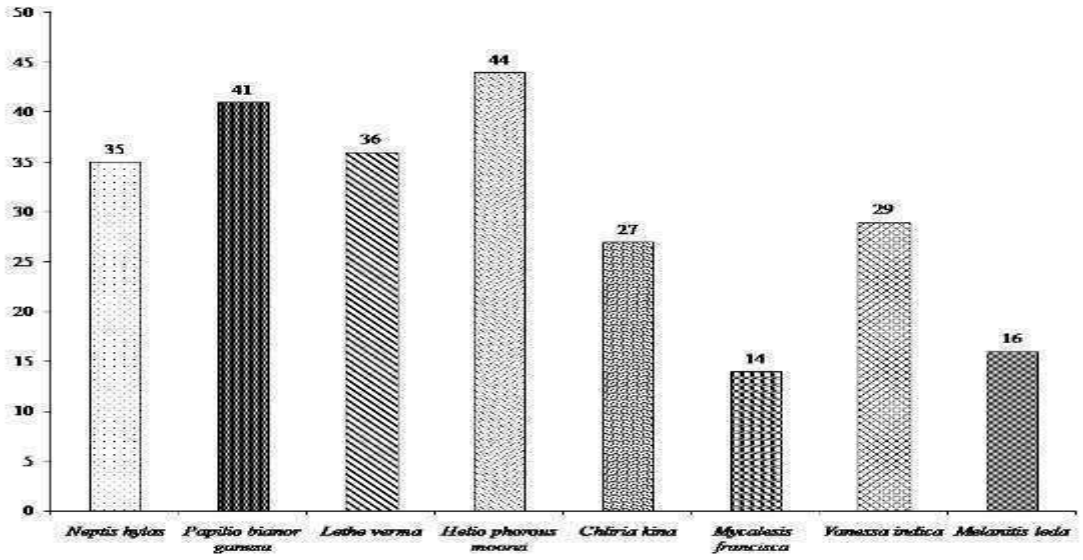


Figure 18. Abundancy in lower stream

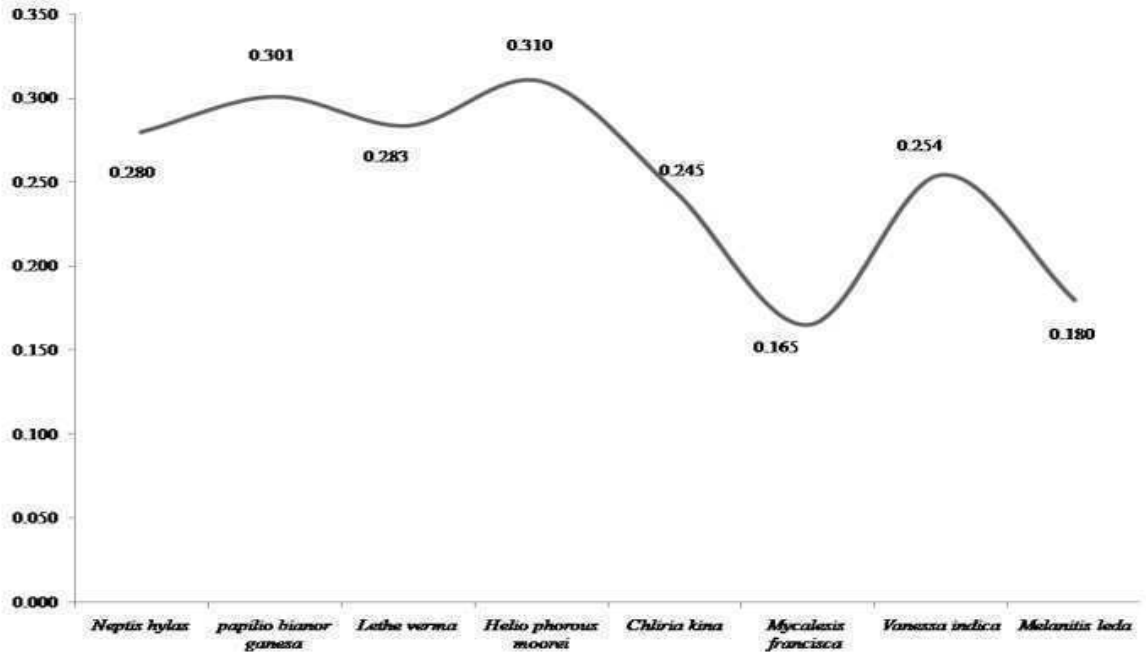


Figure 19. Diversity index in lower stream

Upper stretch of Nika Chhu

Family dominancy

In the Upper stream (TyHE Dam site to till Chhuserbu Confluence of Nika chhu stretch), Study has recorded three families of butterflies. Observation of butterflies in upper stream was different from the lower stream. Upper stream consist of *Pieridae* (66.28%, *n* = 57), followed by *Lycaenidae* (24.42%, *n* = 21) and the least was *Nymphalidae* (9.30%, *n* = 8). Of having three families representing the upper stream, there are four genera and four species within the family (Figure 18). This four species were *Celastrine huegelii* (Large Hedge Blue), *Colias fieldii* (Dark Yellow Clouded), *Pieris brassicae* (Large Cabbage White) and *Venessa indica* (Indian Admiral).

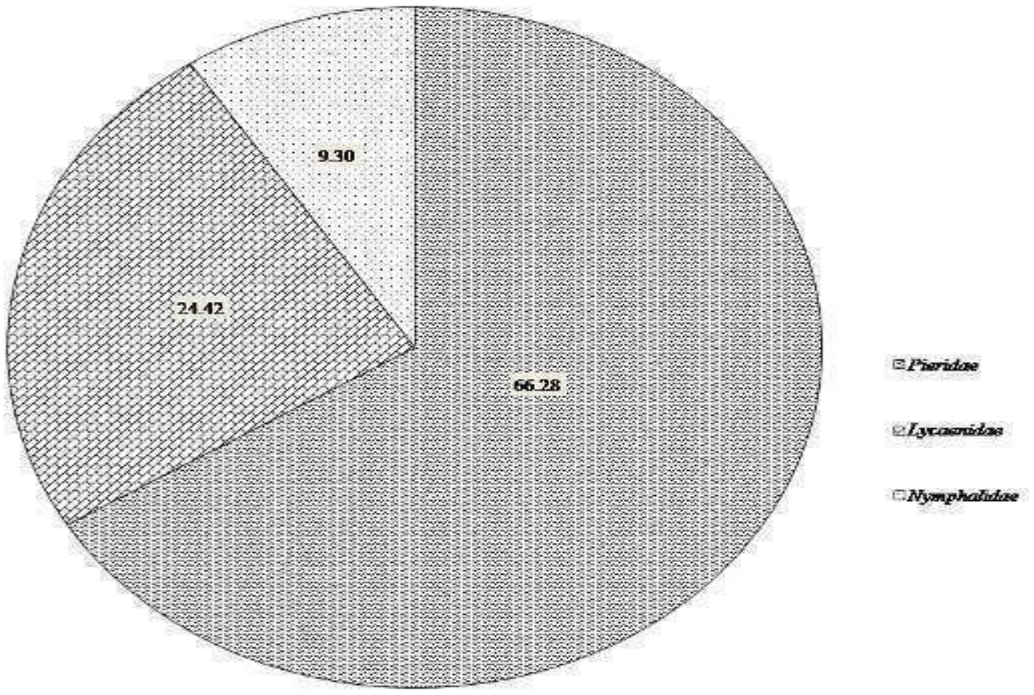


Figure 20. Order wise dominancy in upper stream

Species abundance and diversity index

Similar with lower stream, the species abundance and the diversity index of the upper stream was also examined. While investigating the abundance and diversity of the upper stream, the overall individuals and diversity index of the upper stream was n = 107 and H' = 1.334 respectively. Moreover, species wise abundance and the diversity index were also calculated. The results provide a species rank in following order as per abundance and diversity index. *Pieris brassicae* (Large Cabbage White) > *Venessa indica* (Indian Admiral) > *Celastrine huegelii* (Large Hedge Blue) > *Colias fieldii* (Dark Yellow Clouded). *Pieris brassicae* consist of (A = 40, H' = 0.368, 37.38%) representing the highest individuals in the upper stream. It was followed by *Venessa indica* (Indian Admiral) with (A = 29, H' = 0.354, 27.10%), *Celastrine huegelii* (Large Hedge Blue) by (A = 21, H' = 0.320, 19.63%), and the lowest individual of the species in the upper stream was observed to be *Colias fieldii* (Dark Yellow Clouded) comprising of (A = 17, H' = 0.292, 15.89%), also shown in Figure 19 and 20.

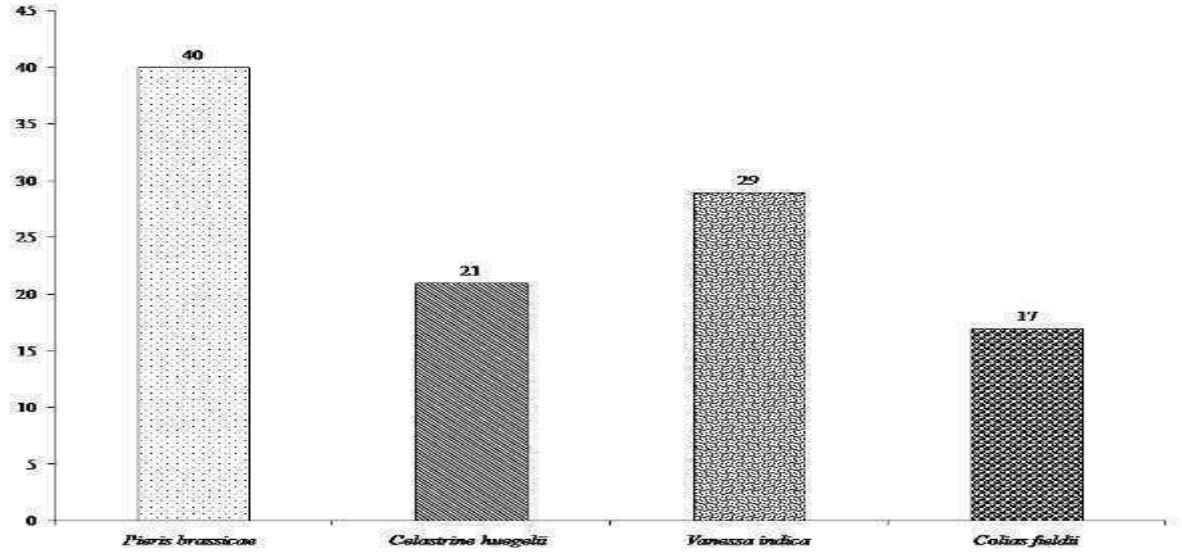


Figure 217. Abundancy in upper stream

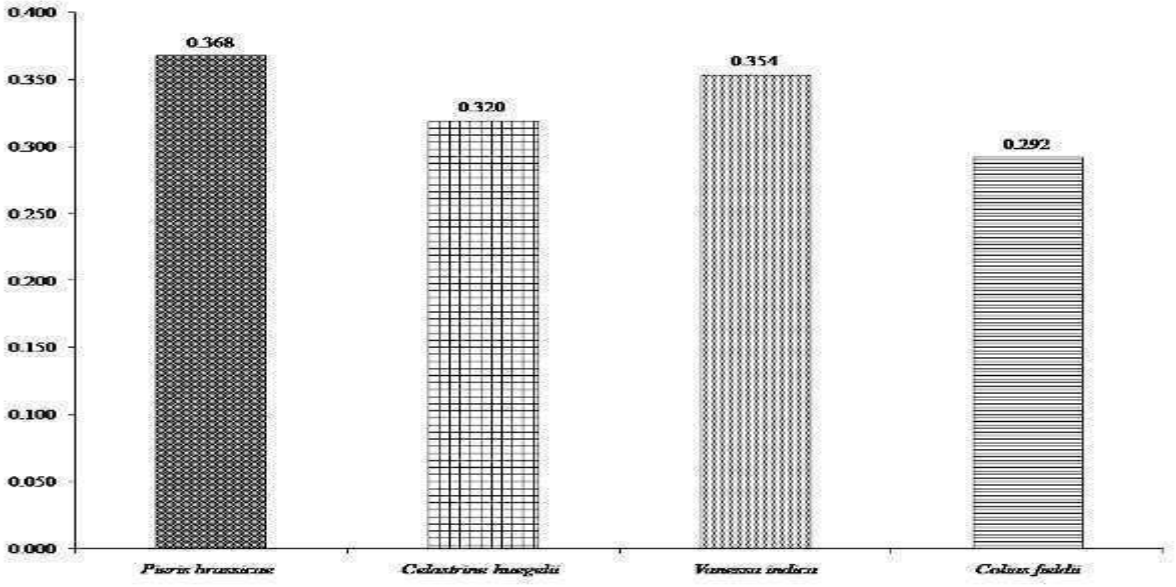


Figure 22. Diversity index in upper stream

Over all Family dominancy

From the stretch of Nika Chhu that has been designated as a study area, 4 families of butterflies with 11 genera and 11 species are obtained. Families included in the reports were *Nymphalidae* representing 45.24 % (*n* = 157), Followed by *Lycaenidae* with 26.51% (*n* = 92), Pieridae by 16.43% (*n* = 57) and the least was represented by *Papillionidae* consisting of 11.82% (*n* = 41) as

shown in Figure 21, those 11 species are *Celastrine huegelii* (Large Hedge Blue), *Chiliria kina* (Blue Tit), *Colias fieldii* (Dark Yellow Clouded), *Helio phorous moorei* (Azure sapphire*)*, *Letha verma* (Straight banded tree brown), *Melanitis leda* (Common Evening Brown), *Mycalesis francisca* (Himalayan Lilacine Bushbrown), *Neptis hylas (*Common Sailer), *Papilio bianor ganesa* (Common Peacock), *Pieris brassicae* (Large Cabbage White) and *Venessa indica* (Indian Admiral).

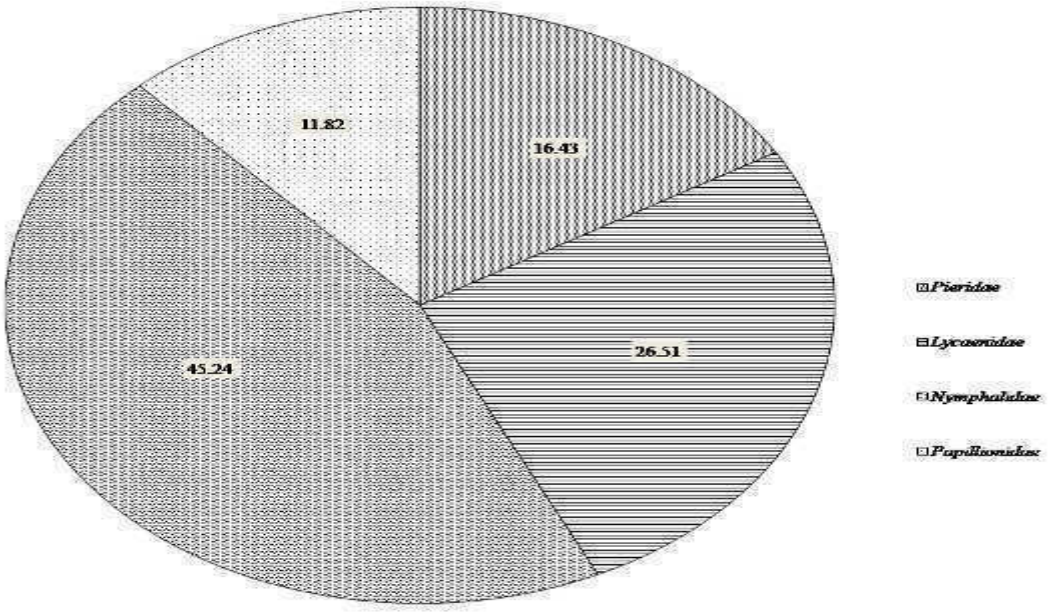


Figure 83. Overall order wise dominancy in the study area

Overall species abundance and diversity index

In the entire period of study, 349 individuals of different species were recorded from four families, 11 genera and 11 species. Likewise, the diversity index for the entire study area was *H*' = 2.039 (Figure 22 and 23). Of total, *Venessa indica* (Indian red admiral) was the individual, that has been encountered the most. In context with the abundance and the diversity index of individuals, *Venessa indica* (A = 58, *H'*= 0.298, 16.62%) is the highest. Followed by *Helio phorous moorei* t(A = 44, *H'* = 0.261, 12.61%), *Papilio bianor ganesa* (A = 41, *H'* = 0.252, 11.75%), *Pieris brassicae* (A = 40, *H*' = 0.248, 11.46%), *Letha verma* (A = 36, *H'* = 0. 0.234, 10.32%), *Neptis hylas* (A = 35, *H'* = 0.231, 10.03%), *Chiliria kina* (A = 27, *H*' = 0.198, 7.74%), *Celastrine huegelii* (A = 21, *H'* = 0.169, 6.02%), *Colias fieldii* (A = 17, *H*' = 0.147, 4.87%), *Melanitis leda* (A = 16, *H'* = 0.141, 4.58%) and *Mycalesis francisca* (A = 14, *H*' = 0.129, 4.01%).

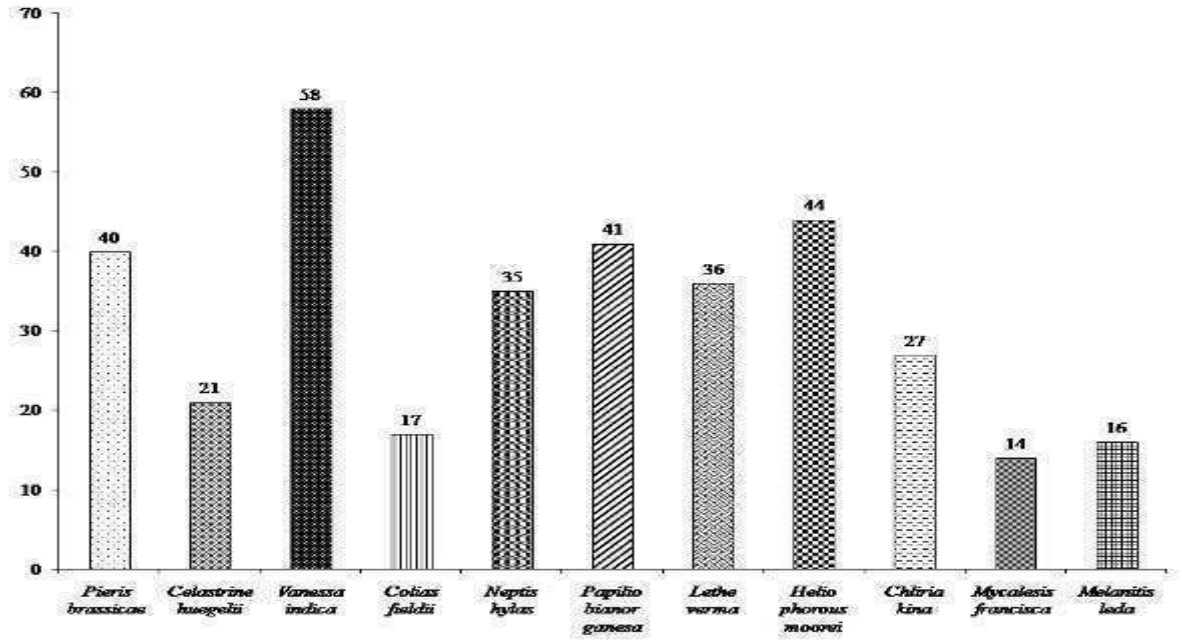


Figure 24. Overall abundancy

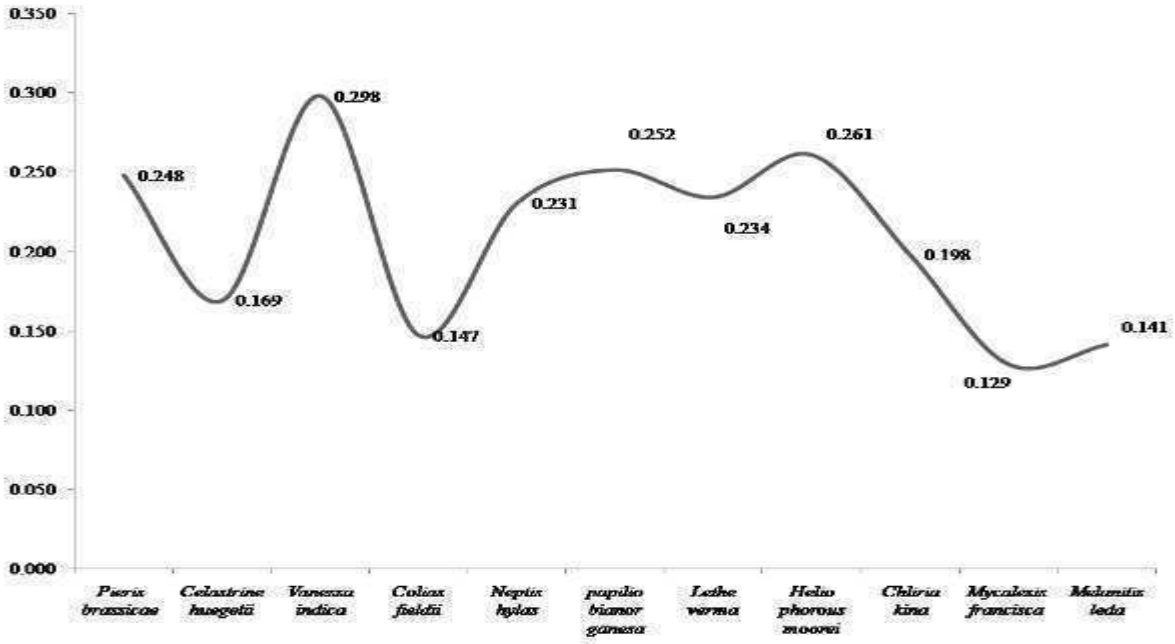


Figure 25. Overall diversity index

Discussion

Family Dominancy

The result clearly indicates that the dominating family in the study area is *Nymphalidae* and least dominating family is *Papilionidae*. Many researchers have obtained similar results in dominancy of families however; the least dominating family has been differing. Singh (2011) reported 84 species of *Nymphalidae* as dominating families and 12 species under *Pieridae* as a least dominating family. Wangdi *et al*., (2012) reported 186 species of *Nymphalidae* as a dominating family. Nidup *et al.* (2014) recorded 42 species of *Nymphalidae* as a largest family in and around Phobjikha valley. Being *Nymphalidae* family, a largest in the world, comprising of 6000 species could be the main reason for obtaining such similar results. Further *Nymphalidae* and *Lycaenidae* is observed to be most common family in the study area due to its presence and occurance in both stream (Upper and Lower stream).

Species Abundance and Diversity

From the above mention description and figures, the study provides the most common and highly abundance individual inhabiting the Nika Chhu stretch is predominated by *Venessa indica*. While, going through ecological behaviour of individuals, the highest recorded individual - *Venessa indica* has a long range of habitat. Singh (2011) reported that *Venessa indica* is found till 3900 metre above sea level throughout the year. Moreover, it is said to be preferring banks along the stream, openings and edges. Similar report is also claimed by Nidup *et al.* (2014) that *Venessa indica* is seen in 3500 metre above sea level and is mostly found active from March – October. On contrast, the lowest recorded individual – *Mycalensis francisca* is reported to be found in altitude below 1700 metre above sea level and prefer undergrowth forest habitat (Singh, 2011). Such studies exactly align with the findings of this study, as *Venessa indica* has ideal habitat to occupy the Nika Chhu streach of river in comparing with other individual species. Observation in this study claims that *Venessa indica* is found throughout the stretch of Nika Chhu, which is designated as study area, altitude ranging from 1405 – 2567 metre above sea level. Whereas, *Mycalensis francisca* is found only in lower stretch of Nika Chhu which has altitude ranging from 1405-1852 meter above sea level.

This study has an information which reveals that both abundance and diversity of butterfly is higher in the lower stream (n = 242, H' = 2.017) as compare to the abundance and diversity

index (n = 107, H' = 1.334). Such could be the attribution due to ecological adaptation of butterflies. A phenomenon of migration is seen in every butterfly, they may be in search of food, mate, habitats, and to escape from predators / adverse climatic conditions. Haribal (1992) has classified the types of migration by butterflies; Local spread is movement within ten to hundred meters from the area where the butterfly is emerged. Dispersal is random and aimless movement from area where it emerges to another location which may be or may not be suitable. Migration is a medium and long distance directional movement from one suitable location to another suitable location, which may be hundreds of kilometres (km) from where they emerge. In this context, as the upper stream has an altitude ranging from 2322 – 2567 metre above sea level, butterflies could have migrated in lower altitude to escape from harsh climatic conditions and in search of food.

Nevertheless, the conservation status on the butterflies reported from the study area is not remarkable. IUCN redlist and Global Butterfly Information System has a classification of butterflies as per the global conservation status. The recorded butterflies from the study area were not included in any kind of status in IUCN redlist. Global Butterfly Information System has mentioned about their status as acceptance on species but have no remarks on conservation status. Therefore, the recorded species of butterfly from the study area can has its own conservation needs but is not as much to concern over.

Suggestion

Over the short period of study time, this study managed to record 349 individuals from 11 different species and four families. The study provides *Nymphalidae* as a dominating family comprising of 45.24% for entire study area. It further shows that the abundance of *Venessa indica* is high (16.62%). Though the study was carried out in very short period of time, finding and out turn of the result is satisfactory. This clearly indicates that further systematic research with longer period of time is essential for getting a detailed periodic estimate of butterfly in the area.

Researchers view that preference of habitat for butterflies various greatly according to geographic environmental factors such as open space, edge, river banks, closed canopy, availability of food, abiotic disturbance and others. Given the short period for study, this study couldn't incorporate such variables. Therefore, this study suggest authority to speed up the

longer period of study including afore mentioned variables to understand the roles played by the different variables in distribution of Butterflies.

Reference

Dorji, S. (2014). Butterflies in and around Phobjikha Valley. RSPN: Thimphu

Haribal, M. (1992). The Butterflies of Skkim Himalaya and their natural history. *Nature Conservation Foundation (SNCF)*, pp. 207. Gangtok, Sikkim

Laaksonen, J., Laaksonen, A., Itamies, J., Rytkonen, S & Valimaki, P (2006). A new efficient bait-trap model for Lepidoptera surveys – the "Oulu" model. *Entomologica Fennica*. 17: 153-160

Leps, J. & Spitzer, K. (1990). Ecological determinants of Butterfly communities (Lepidoptera, Papilionidae). In the Tam Dao Mountains, Vietnam. *Acta Entomol. Bohemoslovaca*. (87): 182-194

Nidup, T., Dorji, T. & Tsheing, U. (2014). Taxon diversity of butterflies in different habitat types in Royal Manas National Park. *Journal of Entomology and Zoology Studies.* 2 (6): 292-298

Ramesh, T., Hussain, J. K., Selvanayagam, M., Satpathy, K. K., & Prasa, R. V. M. (2010). Patterns of diversity, abundance and habitat associations of butterfly communities in heterogeneous landscapes of the department of atomic energy campus at Kalpakkam, South India. *International Journal of Biodiversity and Conservation,* 2 (4): 75-85

Singh, A.P. (2011). Butterflies of India. Om books international: Uttar Pradesh, India

Sundufu, A. J. & Dumbuya, R. (2008). Habitat preferences of butterflies in the Bumbuna forest, Northern Sierra Leone. *Journal of Insect Science*. 8 (64): 1-7

Singh, I.J. (2014). Species catalogue of rare and threatened butterflies and moths of Bhutan. Research Gate. <http://www.researchgate.net/publication/267864567>. Accessed 5 December 2015

Tiple, A. D. (2012). Butterfly species diversity, relative abundance and status in Tropical Forest Research Institute, Jabalpur, Madhya Pradesh, Central India. *Journal of Threatened Taxa* 4 (7): 2713–2717

Van der Poel, P. & Wangchuk, T. (2007). *Butterflies of Bhutan. Mountain, hills and valleys between 800 and 300m.* Royal Society for Protection of Nature (RSPN). Thimphu, Bhutan. Colombia, Pamamericana Formase Impresos S.A

Wangdi, S., K. Wangdi, Sherub, R. Wangdi, S. Drukpa, M. Harada, T. Aoki, S. Yamagchi, M. Saito, Y. Igarashi, Y. Watanabe & M. Yago (2012). Butterflies of Trashiyangtse Valley, eastern Bhutan (Part 1). Butterflies (Teinopalpus). *The Butterfly Society of Japan (Teinopalpus).* No. 62: 16–28

Annexure

Annexure I: Sampling location for Upstream and Low stream

Plot #	Name of location	Alt	N	E
		Upstream		
1	Yala	2322	27°27'16.0"	90°21'57.2"
2	Drangla	2393	27°27'35.7"	90°21'30.9"
3	Chendepji Chorten	2399	27°28'09.1"	90°21'07.9"
4	Pasture	2439	27°28'57.3"	90°20'32.6"
5	Chuserbu	2507	27°29'53.6"	90°18'48.5"
6	Above chuserbo	2567	27°30'23.4"	90°18'10.9"
		Low stream		
1	Mangdechu confluence	1405	27°26'01.5"	90°27'48.7"
2	Old bridge	1579	27°26'48.1"	90°26'21.0"
3	Above old bridge	1618	27°26'60.2"	90°25'19.2"
4	New bridge	1704	27°26'84.2"	90°24'24.2"
5	Above new bridge	1802	27°26'98.2"	90°23'19.2"
6	Tsheringma drupchu	1852	27°26'99.7"	90°22'29.4"

Annexure II: Taxonomic classification of butterflies

Order: Lepidoptera

Family: Pieridae

Genus: Pieris

Species: P. *brassicae*

Binominal name: *Pieris brassicae*

Authority: (Linnaeus, 1758)

Order: Lepidoptera

Family: Lycaenidae

Genus: Celastrina

Species: C. *huegeli*

Binominal name: *Celastrina huegeli*

Authority: Moore, 1882

Order: Lepidoptera

Family: Nymphalidae

Genus: Vanessa

Species: V. *indica*

Binominal name: *Vanessa indica*

Authority: (Herbst, 1794)

Order: Lepidoptera

Family: Pieridae

Genus: Colias

Species: C. *fieldii*

Binominal name: *Colias fieldii*

Authority: Menetries, 1855

Order: Lepidoptera

Family: Papilionidae

Genus: Papilio

Species: P. *bianor*

Binominal name: *Papilio bianor*

Authority: Cramer, 1777

Order: Lepidoptera

Family: Nymphalidae

Genus: Neptis

Species: N. *hylas*

Binominal name: *Neptis hylas*

Authority: (Linnaeus, 1758)

Order: Lepidoptera

Family: Nymphalidae

Genus: Lethe

Species: L. *verma*

Binominal name: *Lethe verma*

Authority: Hubner, (1819)

Order: Lepidoptera

Family: Lycaenidae

Genus: Heliophorous

Species: H. *moorei*

Binominal name: *Heliophorous moorei*

Authority: Hubner, (1819)

Order: Lepidoptera

Family: Lycaenidae

Genus: Chliaria

Species: C. *kina*

Binominal name: *Chliaria kina*

Authority: (Hewitson, 1869)

Order: Lepidoptera

Family: Nymphalidae

Genus: Melanitis

Species: M. *leda*

Binominal name: *Melanitis leda*

Authority: (Linnaeus, 1758)

Order: Lepidoptera

Family: Nymphalidae

Genus: Mycalesis

Species: M. *francisca*

Binominal name:

Authority: (Stoll, 1780)

SECTION VI: CONCLUSION AND REFERENCES

Conclusion

This report comprises an environmental study along Nika Chhu through using biological indicator such as fishes, macro-invertebrates and riverine butterflies. Report provides additional information on the diversity – species composition, species abundance, diversity index, its habitats, distributions and factors influencing the existences of fishes, macro-invertebrates and butterflies along the Nika Chhu. A long term study with larger sampling intensity is suggested to determine the relation between habitat types and environmental factors, which ultimately influences the distribution of any species.

It has been a great privilege for me to work on this diverse and inspiring topic. Many important ecological scholars have devoted considerable time to the subject of environment and freshwater ecology, yet we understand them only superficially. I now came to release why environmental and ecologist talks so enthusiastically about the subject everywhere. I hope that others may use my small contribution to the subject to promote a greater understanding of how these systems work and to conserve them for future generations.

Reference

Chhopel, G.K. (2014). Sustainability of bhutan's hydropower. *Hydro Nepal*. 14

Dorji, S. & Wangchuk, T. (2014). *Freshwater fishes of royal manas national park*. Gelephu: RMNP

Dubey, G.P. (1978). Survey of the waters of bhutan physiography and fisheries potential. FAO, Rome

Eby, L., Lowe, W. & Gurung, D.B. (2009). Priorities and Protocols for freshwater monitoring. In Wildlife Research Techniques in Rugged Mountainous Asian Landscapes, eds.Mills,L.S., Tempa,T & Cheng,E. 1st eds., pp. 185-195. Bumthang: UWICE

Gurung, D.B. & Thoni, R.J. (2015). *Fishes of Bhutan: A preliminary checklist*. CRDS: College of Natural Resources

Gurung, D.B., Dorji. S., Tshering, U. & Wangyel. J,T (2013). An annotated checklist fishes from Bhutan. *JournalforThereatenedTaxa*.5(14):4880-4886. doi:org/10.11609/ JoTT. o3160. 4880-6

McClelland, J. (1839). Indian Cyprinidae. *Asiatic Researches (Bishop's College Press, Calcutta)* 19: 217–471.

Maul, J.D. (2004). The influence of stream habitat and water quality on macroinvertebrates communities in degraded streams of northwest Mississippi.*Hydrobiologia.* 518, 79-94

NBC (2009). *Bhutan-biodiversity action plan*.Thimphu:National Biodiversity Center

NEC (2011). *Biodiversity*. Thimphu:National Environment Commission

Petr,T. (1999). Cold water and fisheries in Bhutan; Report. Rome, FAO.

Quammen, D. (1996). *The Song of the Dodo: Island Biogeography in an Age of Extinction.* Touchstone: New York

Rajvanshi, A., Roshni A., Vinod, B. M., Sivakumar, K., Sathyakumar,S., Rawat, G.S., Johnson, J.A., Ramesh, K., Dimri, N. & Maletha, A. (2012). Assessment of cumulative impacts of hydroelectric projects on aquatic and terrestrial biodiversity in alaknanda and bhagirathi basins, uttarakhand. Wildlife Institute of India. pp. 203

Tenzin, K. (2006). The design of a non-lethal fish monitoring program for rivers in Bhutan. Canada: University of New Brunswick.

Tshering, S. & Tamang, B. (2004). Hydropower - Key to sustainable, socio-economic development of Bhutan. Thimphu: Bhutan

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Department of Livestock
Ministry of Agriculture and Forest
National Research Center for Riverine and Lake Fisheries
རྒྱལ་ཡོངས་གཙང་ཆུ་དང་མཚོ་ཉའི་ཞིབ་འཚོལ་ལྷེ་བ།

Baseline Study Report on Aquatic Flora and Fauna of Tangsibji Hydro Energy Limited for Nikachu, Trongsa Dzongkhag

Prepared By:

Sangay Norbu

Fishery Ecology and Environment Unit

National Research Center for Riverine and Lake Fisheries

April 2016

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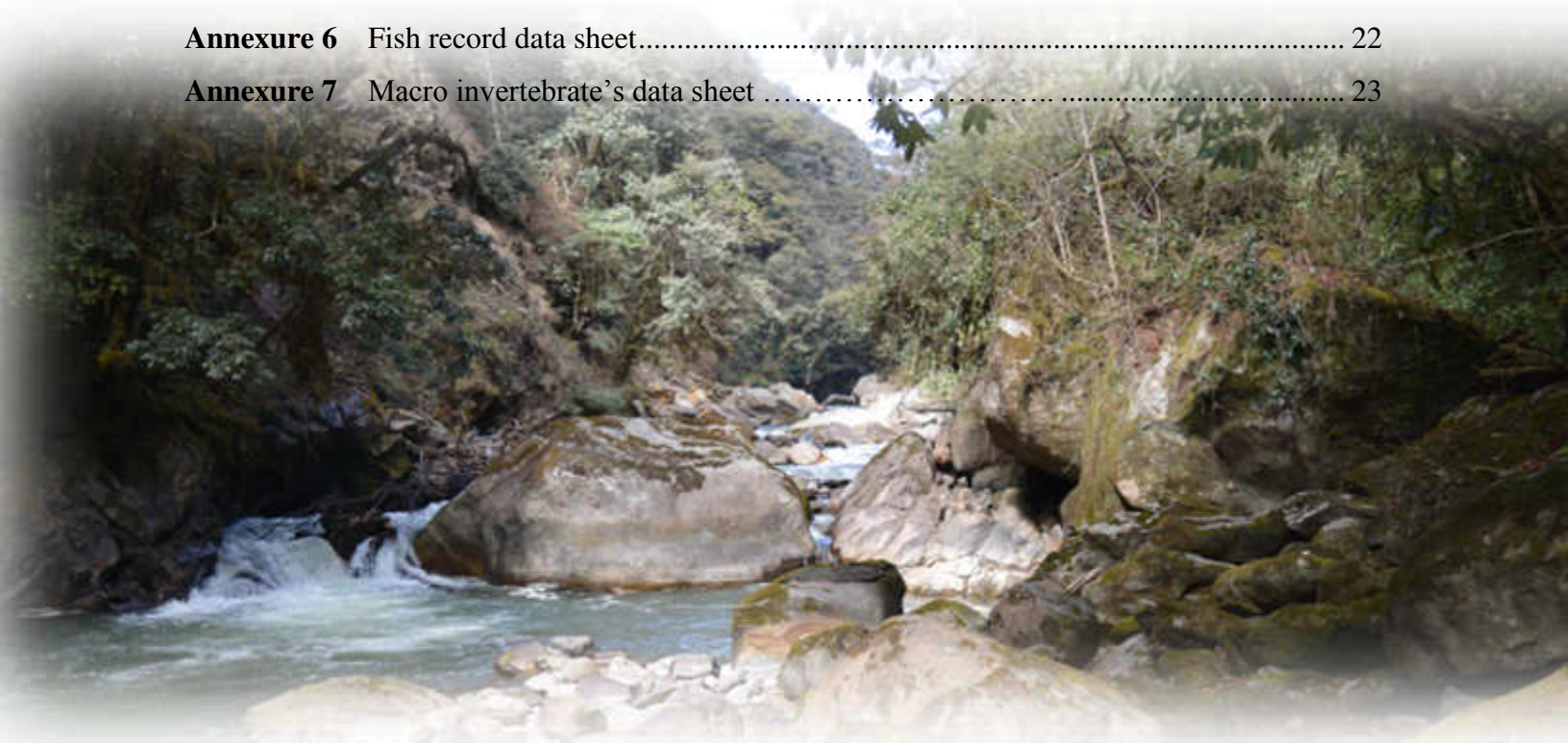

1 Introduction

Bhutan with vast natural resources drives to develop the growth of green power generation for country economics progress. The power sector in a country depend on water energy to generate clean energy for delight of people and country. The power sector has targeted Nikachu to construct the Hydro dam, producing 118 megawatts and environment impact assessment has prepared. During the pre-construction phase, there will intrude original habitat of all the living being including aquatic and terrestrial animal. This includes construction of road, construction of worker camps, clearing forest, transit of vehicle for transportation/human will ultimately disrupt the environment. These will affect natural habitats that are inhabitant nearby place. Therefore, baseline data will provide original description of natural habitat intact. These will show the significant impact on loss of biodiversity like aquatic fauna and other terrestrial animals that are dwelling. Considering all this points, the baseline database will be collected to ensure the proper planning and action that appropriate before the immense area degradation will materialize. The prerequisite database like pre-dam construction phase will guide to plan the management plan and mitigation measures on aquatic biodiversity. Without sufficient data on baseline it would be difficult to track the monitoring program during construction and post construction phase for biodiversity existent.

This study is aimed at developing database on aquatic flora and fauna during pre-construction phase. This will give us true picture database that will ensure the cause and effect of the dam construction phase. Other than this, it will guide us to develop the plan how to mitigate these problem.

2 Objective

The main objectives of this study are follows:

- To undertake fish fauna assessment: species composition and distribution along Nikachu and Mangdechu.
- To collect data on macro-invertebrates/planktons.
- To undertake study on river morphology and water quality.

3 Material and Methods

3.1 Location of the study

Nikachu is located in Tangsibji gewog, Trongsa Dzongkhag. Tangsibji gewog consist of seven villages and 232 households. It covers an area of 371.6 Km² and gewog is border with Wangdiphodrang Dzongkhag to the west, Langthil gewog to south and Drakteng gewog to the east. Nikachu lies below or pass through the east-west highway with 27.45079 north and 90.36884 east given in (Fig 1). Due to this eastern highway the people are benefiting for socio- economic development.

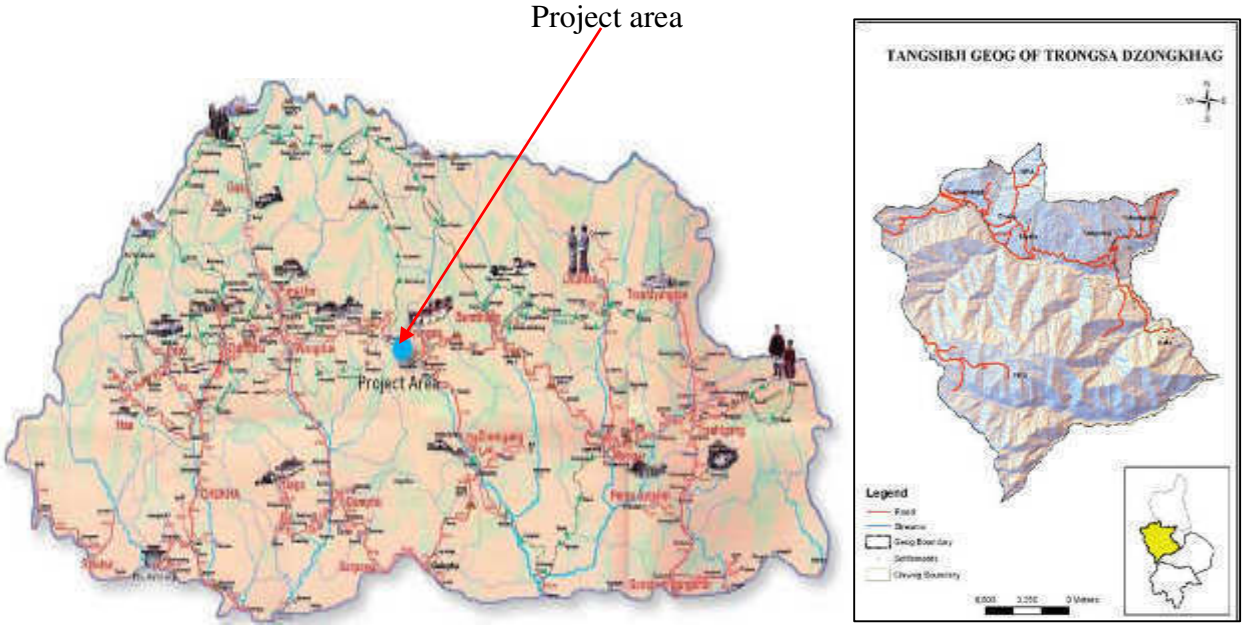

Figure 1. Location of project (Photo sources from THyE website)

3.2 Sampling area

Study sites were selected according to zone and station marked to represent even distribution of samples area. Samplings were carried out in all the tributaries for Nikachu and Mangdechu. The GPS coordinates were recorded in all sampling sites to provide fish composition and distribution as shown in (Fig.2).

3. 2.1 Upstream

Two zone of 1 km with one sample station each in Nikachu was sample in upstream of the dam site. The main reason to study the upstream of the dam site is to ensure the fish movement/migratory pattern and water quality as shown in (Table 1).

Table 1 Showing the GPS coordinates of fishing stations

Zone	Station	Northing	Easting	Altitude(M)	Total KM Stretch	Remarks
I	I	27.45079	90.36884	2170	0.53	Upstream
II	I	27.42379	90.64230	2147	0.80	

3.2.2 Downstream

From downstream two zone of 5 km each with two sample stations each in Nikachu and three fishing station in Mangdechu were samples as given (Fig.2). The main reason to study the downstream of the dam site was to collected data on quality of water and fish movement/migratory pattern, habitat and other macro invertebrates' existent afore construction phase. After construction there will be disrupt and alter of water flows that will make completely de-watering river reaches and the life contain, which will be unravel the ecological web of a river system. This will act as significant database to assure before and after construction on aquatic flora and fauna.

Table 2 Showing the GPS coordinates of fishing stations

Zone	Station	Northing	Easting	Altitude (M)	KM Stretch	Remarks
	ADIT 1	27.44737	90.39435	2074	2.16	Downstream
III	ADIT 2	27.44460	90.30568	2002	2.88	
	ADIT 3	27.43282	90.44937	1478	4.50	
IV	Confluence	27.43326	90.46263	1403	1.50	

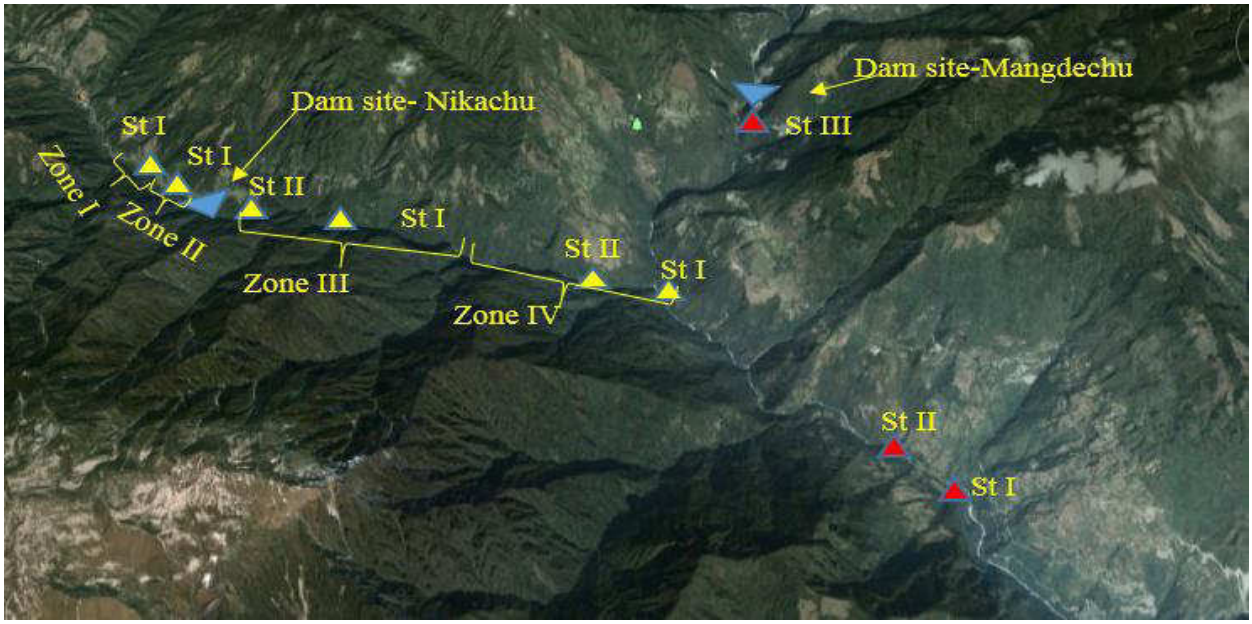

Figure 2 Showing the represented zone and station for sampling

3.3 Sampling method

3.3.1 Fish fauna

Fish sampling was done to obtain aquatic data. To obtain fish species different sampling method were use. The sampling method includes like cast net, rod and line and elector fisher. Catch and release method was applied and only fish species required for specimen were collected.

3.3.2 Macro- invertebrate

Macro invertebrate was samples by using 1mm scoop net/kick net/Hapa fish net and collect by hand from underneath of stone and cliff rock and other habitat from sample station. This was done by disturbing the substrate with hands or feet so that the insects are dislodged and washed downstream into the net. The required specimen was collected for further study.

3.3.3 Basic physicochemical measurements

The basic water quality data was study and record like temperature, Dissolved Oxygen (DO) and pH from all the sampling sites/ station. The other data like hydrology such as river width, water depth, flow rate, volume of discharge per second was also study. The

discharge per second was estimate using the standard formula of float method or selecting a cross-section method.

$$\mathbf{Q = W \times Dm \times Vm}$$

Where Q = Discharge in cubic meter/sec, W = Water/Channel width, Dm = Mean depth of river, and Vm = Average velocity in meter/sec.

3.4 Specimen collection and preparation

For each sampled fish species, a specimen was collected and fixed using standard stock solution of 10% formalin. After two weeks specimens was transferred to 70% ethyl alcohol for permanent preservation in specimen jar with proper labels. For the specimen collected for macro invertebrates was preserved in 75% ethyl alcohol. The sample specimens was brought to National Research Center for Riverine and Lake Fisheries, Haa for identification and preservation.

3.5 Data analysis

The data was analysis using following methods

3.5.1 Filed level analysis

The sample fish and macro invertebrates was study visually in the field and recorded.

3.5.2 Laboratory analysis

Those fish species and macro invertebrates that not able to identify in the field will transport to NRCR&LF laboratory for species confirmation and record.

3.5.3 Computed in computer software

The data was process in Microsoft excel for calculation of macro invertebrate percentage and water flow discharge.

4 Result and Analysis

4.1 Composition of fish fauna in Nikachu

An extensive study and experimental fishing at all the sampling sites were conducted (Zone I to Zone IV). A detailed list of fish species, their local name and scientific name and common name is presented in (Table 3) and (Annexure 1 & 2). During study it was revealed that one species of fish (Brown trout) was caught in the upstream of the dam site for entire zones (I & II) with sample stations (I & I).

Similarly in the downstream the study revealed that *salmon truttra* was present in all the fishing zones but *Schizothorax* species was only found in Nikachu-Mangdechu confluence and above 100 m stretch (Zone IV, station I). The study also revealed that there was no fish found in all the contributing tributaries of Nikachu (Nyelalumchu, Banglachu and Zalamchu). The *salmo truttra* and *Schizothorax* is not migratory in nature. The *Schizothorax* will move upstream in summer for spawning and downstream in winter season.

Table 3 Detail list of fish species

Order	Family	Species	Common name	Local Name
Salmoniformes	Salmonidae	*Salmo trutta*	Brown Trout	Jya Nye
Cypriniformes	Cyprinidae	*Schizothorax* sp.	Snow Trout	Yuel Nye
Cypriniformes	Cyprinidae	*Schizothorax richardsonii*		Yuel Nye

4.2 Composition of fish fauna in Mangdechu

During the baseline study three sample station were done extensive study to reveal the fish composition in Mangdechu, a total of two order and two family fish were found as presented in (table 4). The maximum catch was *Schizothorax richardsonii* and *Schizothorax* sp in station I & II and only one brown trout was caught from station II as given in (Annexure 2). There was zero catch in station III (Mangdechu dam site area). This could be due to disturbance by construction worker in the day time. The most of fish was caught using cast net and zero caught in Rod and line.

Table 4 Detail list of fish species in Mangdechu

Order	Family	Species	Common name	Local Name
Salmoniformes	Salmonidae	*Salmo trutta*	Brown Trout	Jya Nye
Cypriniformes	Cyprinidae	*Schizothorax* sp.	Snow Trout	Yue Nye
Cypriniformes	Cyprinidae	*Schizothorax richardsonii*	Snow Trout	Yue Nye

4.3 Composition of the macro invertebrate fauna in Nikachu

A total of nine taxa groups and 20 species macro invertebrates were recorded at upstream and downstream of dam sites. In terms of species diversity in upstream the fauna was dominated by Diptera (23.38%), Megaloptera (16.05%), Coleoptera (14.08%), Plecoptera (16.05%) and least with architaneioglossa (1.79%) were recorded as shown (Fig.3). A full list of the species is given in (Table 5).

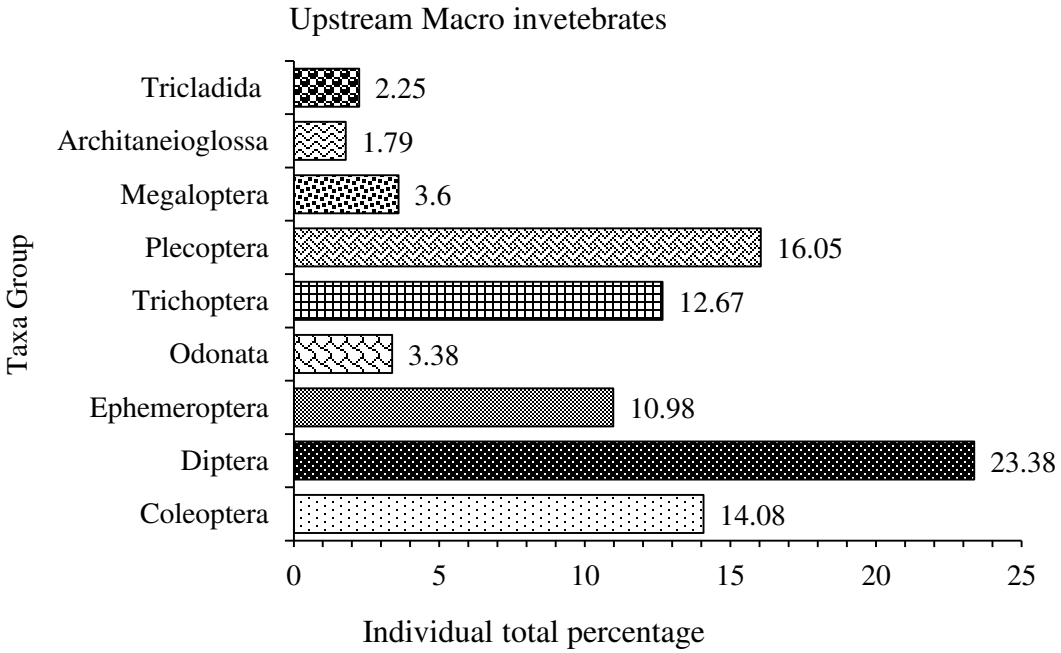

Figure 3 Taxa group with individual total percentage present

In downstream study it was found almost similar to the upstream. The most macro invertebrates was Diptera (32.49%), Megaloptera (20.16%), Coleoptera (13.44%) and Ephemeroptera (10.64%) were recorded as shown (Fig.4)

The study revealed that macro invertebrate were found more significantly in less intensity of sunlight fall with canopy coverage. The less macro invertebrate was found in open river bank and cascade sites compared to pool and riffle sites.

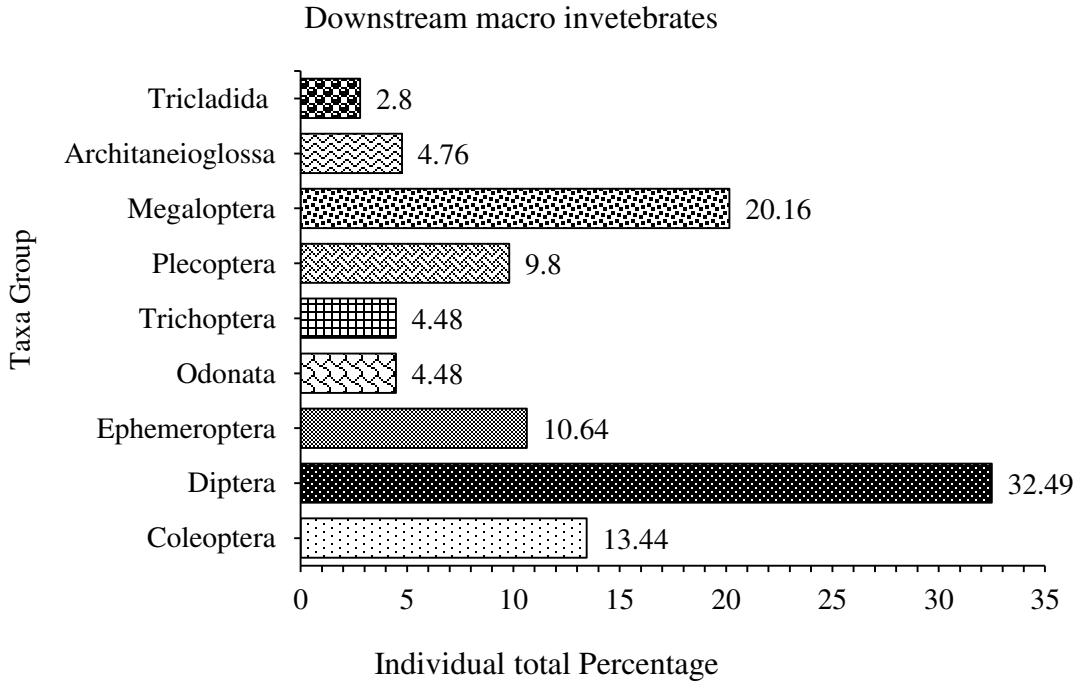

Figure 4 Taxa group with individual total percentage present

Table 5 Detail list of Macro invertebrates

Phylum	Order	Family	Scientific Name	Common Name
Arthropoda	Coleopetera	Psenhenidae	*Coleopetera psenhenidae*	Aquatic beetle
		Dytiscidae	*Coleoptera ptilodactylidae*	Diving Beetle
		Chrysomelidae	*Coleoptera chrysomelidae*	Reed beetle
	Diptera	Chironomidae	*Diptera chironomidae*	Nonbiting midges
		Empididae	*Diptera empididae*	Moth flies
		Tipulidae	*Diptera tipulidae*	True flies
		Simuliidae	*Diptera simuliidae*	Black flies
		Simuliidae	*Simuliidae* sp	
		Tipulidae	*Tipulidae* sp	
	Ephemeroptera	Oniscigastridae	*Ehemeroptera Oniscigastridae*	May fly
		Leptophlebiidae	*Ephemeroptera Leptophelbidae*	
	Odonata	Anisoptera	*Odonata anisoptera*	Dragonflies
	Trichoptera	Philopotamidae	*Trichoptera philopotamidae*	Caddisfly
		Hydropsychidae	*Trichoptera hydropsychidae*	Caddisfly
	Plecoptera	Gripopteryidae	*Plecoptera gripopteryidae*	
		Perloidae	*Pleacoptera perloidae*	Stonefly
		Eustheniidae	*Plecoptera eustheniidae*	
	Megaloptera	Corydalidae	*Megaloptera corydalidae*	Dobsonfly
Mollusca	Architaneioglossa	Viviparidae	*Notopalasublineata*	River Snails
Platyhelminthes	Tricladida	Procerodidae	*Procerodidae* sp	Flat worm

4.4 Basic physicochemical measurements

The water quality test was also executed during study in Nikachu and its tributaries and Mangdechu. The basic parameter test was performed like temperature, pH and dissolved oxygen (DO). The study revealed that the water parameter remained constant. Whereas in the Mangdechu it change when the elevation changes as presented in (Table 6).

Table 6 Water parameter tested in Nikachu - its tributaries and Mangdechu

Sample Sites	Temperature	Dissolved Oxygen(DO)	pH	Remarks
Nikachu	10.80	10.40	8.00	
Nyalalumchu	9.60	9.60	8.20	Tributaries
Zalamchu	9.50	9.50	8.00	Tributaries
Bangalachu	9.40	9.20	8.20	Tributaries
Mangdechu	11.90	10.10	8.20	

4.5 Assessment of water discharge (Environmental Flow)

Nikachu is a perennial snow and rain-fed river with a marked seasonality in its hydrology due to the monsoon rains. Water flows at the proposed intake site revealed in lean season was 4.02 m^3/s. The discharge will be more at the peak of the monsoon. Water flow below the dam site (Nyalalumchu-Nikachu confluence) revealed more than above dam site. It was found 7.55 m^3/s due to significant contributing tributaries as present in (Table 7). The water discharge will increase when it reaches to Nikachu and Mangdechu confluence. The more additional tributaries joined form right and left side of the catchment area. The water discharge at confluence was not measured due to limitation such as fast flowing, not able cross through and the site was with big boulders.

Table 7 Water flow discharge of Nikachu and its tributaries

Feature	Stations	Discharge (cm^{-3}/s^{-1})	Remarks
Lean Season data	Upstream above dam site	4.02	
	Downstream Below Dam site	7.55	Nyalalumchu-Nikachu confluence
	Nyalalumchu	0.236	Below Dam

	Zyalamchu	0.496	Below Dam
	Bangalachu	0.65	Below Dam

5 Conclusion

The present study is first to report the leans season data on aquatic flora and fauna in Nikachu, Trongsa. The Study mainly focus on fish composition and distribution, macro invertebrates and water discharge along Nikachu. The results revealed that the two fish species is present in entire fishing station. However no single fish was catch in contributing tributaries of Nikachu. Eight taxa and 20 species of macro invertebrates are presents in upstream and downstream of dam site. The basic water parameter measurements such temperature, pH and dissolved Oxygen (DO) were study. Beside this study, the water discharge was measure by using cross sectional method. This was to give a basic idea of environmental flow to sustain the aquatic life after dewatering reached in particularly to lean season.

Annexure 1 list of fish species present in Nikachu and Mangdechu

Salmo truttra (brown trout)

Schizothorax sp (snow trout)

Schizothorax richardsonii (snow trout)

Annexure 2 Details list of fishes sampled

Sl.No	Fish species	Length(cm)	Weight(gm)	Zone	Station
1	Brown trout	24	240	I (upstream 1km stretch)	I
2		12	80		
3		14	95		
4		18	180		
5		13	98		
6		15	104		
7		16	120		
8		12	78		
9		14	90		
10		15	102		
11		13	76		
12	Brown trout	14	97	II(Upstream 1 –km stretch)	I
13		12	79.3		
14		15	123		
15		13	78		
16		17	101.2		
17		16	130		
18		18	137		
19		19	150		
20		23	195.4		
21		22	180.3		
22		12	80		
23	Brown trout	44	220	III (ADIT to Dam)	II
24		17	136		
25		26	240		
26		12	78		
27		14	94		
28		17	110		
29	Brown trout	18	111	III (ADIT 2 to ADIT 1)	I
30		21	160		
31		21.2	162.1		
32		17	103.7		
33		16	104		
34		15	120		
35		14	100.2		
36		16	115.9		
37	Brown trout	16.5	115.9	IV (ADIT 3 to ADIT 2)	II
38		15	112		
39		13	80		
40		12.4	74.3		
41	Brown trout	12	76	IV (Nikachu- Mangdechu	I
42	Snow trout	27	223	confluence to ADIT 3)	
43	Snow trout	57	1.56	Mangdechu -Kyalazam	II

44		26	234		
45		25	220		
46		19	180		
47		24	160		
48		19	110		
49		25	140		
50		20	102		
51		20	105		
52		19.5	102		
53	Brown trout	18	114		
54	Snow trout	19	115		
55		26	146		
56		29	190		
57		18.5	132		
58	Snow trout	17	121	Power house to Kyalazam	I
59		22.6	170		
60		32	220		
61		28	250		
62		29.4	270		
63		23	160		
64		17	116.4		
65		18	116.9		
66		20	123.2		
67		22.2	125.1		
68		24	114		
69		26	155		
70		28	179		
71		29	180		
72		25	124		
73		17	132		
74		18	132.6		
75		28	130		
76		26	150		
77		22	130		
78		23	132		
79		25	120		
80		27	150		
81		23	130		
82		24	114		
83		29	202		
84		30	214		
85		31	270		
86		28.4	240.5		
87		23.6	190		
88		27	230		
89		28	235.1		

90	26.4	201

Annexure 3 Detailed list of Marco invertebrates of Nikachu

1 Coleoptera

1 Coleoptera psenhenidae

2 Coleoptera pupae stage.

3 Coleoptera Dytisicidae (Adult Aquatic beetle)

4 Coleoptera chrysomelidae.

2 Diptera

1 Diptera Chironomidae

2 Diptera Empididae (Crane fly)

3 Diptera simuliidae

4 Diptera Tipulidae


6 Simuliidae sp

7 Tipulidae sp

3 Ephemeroptera

1 Ehemeroptera Oniscigastridae

2 Ephemeroptera leptophelbidae

4 Odonata

1 Odnata anisoptera

5 Trichoptera

1 Trichoptera philopotamidae

2 Trichoptera hydropsychidae

6 Plecoptera

1 Plecoptera gripopteryidae nymph

2 Plecoptera perloidea (adult)

2.1 Plecoptera perloidea (larva stage)

4 Pleacoptera eustheniidae

7 Megaloptera

Megaloptera corydalidae (Dobsonfly)

8 Architaneioglossa

1 Notopalasublineata

9.Flate worm

1 Tricladida (Flate worm)

Annexure 4 Materials require during the sampling period

- Cast Net – 2nos
- Rod and line (Angling) - 1 no
- Scope net/ Kick net/Hapa net - 3nos each
- Weighing balance- 1 no
- Fish Measuring scale- 1no
- DO meter- 1no
- Bucket – 2 nos
- Digital Camera- 1no
- Electro Fisher- 2 sets
- Specimen jar- 10nos
- Formalin- 3bottles
- Cool box- 2nos
- GPS- 1 no
- Sampling bottle- 5nos
- Rope – 100 meters -2nos
- Measuring tape – 100 meters
- Floating object-
- Wader- 3 nos
- Steel tray – 2 nos
- Plastic- 10 nos
- pH meter- 1no
- 4 men Tend- 1 no
- Plastic create- 1no

Annexure 5 Format for Data Collection

Field Data Sheet									
Zone	Station	Width of Stream /River	Depth of water	Area (sq ft) Width x Depth	Run Length (m)	Sec	Velocity in m/sec	Discharge Area x Velocity (cm/s)	Remarks

Annexure 6 Fish record data sheet Location:…… Date:…….

Site		No. of cast	No. Fisherman	No catch/cast	Species
Zone	Station				

Annexure 7 Macro invertebrate's data sheet Location ……. Date ……..

Sites		Type of species	No of record	Remarks
Zone	Station			

Physical Environment Quality Tests at Construction Sites of Nikachhu Hydropower Project
Tangsibji Hydro Energy Ltd., Trongsa,
September 14-15, 2016

1.1 Ambient Air Quality

Respirable Dust Sampler (RDS) Envirotech APM 460 DBL was used to quantify the ambient air quality. Parameters measured were Respirable Suspended Particulate Matter (RSPM), Suspended Particulate Matter (SPM) and Total Suspended Particulate Matter (TSPM) for 24 hours average and the result is provided in **Table 1.**

Table 1: Ambient Air Quality Result

Location	Date	Coordinates	RSPM (µg/m³)	SPM (µg/m³)	TSPM (µg/m³)
Damsite	13-09-2016	27°26'59.44"N 90°22'32.50"E	16.56	3.60	**20.16**
Tashiling (Guesthouse)	14-09-2016	27°27'26.45"N 90°26'53.76"E	14.28	10.71	**24.99**

1.2 Noise Level

LT Lutron Pocket type Sound Level Meter SL-4030 was used to measure the noise level at project sites. The noise level was measured at specific project locations during day and night to record the noise level due to project activities. The average noise levels reading are shown in **Table 2.**

Table 2: Noise Level Result

Location	Date	Coordinates	Noise Level (dB)	
			Day	Night
Damsite	13-09-2016	27°26'59.44"N 90°22'32.50"E	69.8	44.6
Tashiling	14-09-2016	27°27'26.45"N 90°26'53.76"E	64.8	41.2

1.3 Surface Water Quality

The surface water quality tests were carried out using following Kits: turbidity tube, water testing kit from HACH series: HQ40d that has three electrodes (probes) to measure LDO, pH, temperature, conductivity, and chlorine. For water quality test, 3 (three) sampling sites were considered:

1. Chendibji,
2. Upstream of Dam site, and

3. Downstream of Dam site.

These locations were identified with an objective to determine any changes in water quality induced by construction activities and as can be observed in the test results provided in **Table 3**, not much variance is observed.

Table 3: Result for water quality test

Location	Chendibji	U/S Dam Site	D/S Dam Site
Date	**15-09-2016**	**15-09-2016**	**15-09-2016**
Coordinates	27°29'18.24"N 90°20'8.36"E	27°27'0.41"N 90°22'14.14"E	27°26'56.05"N 90°22'20.11"E
pH	8.22	8.35	8.26
LDO (mg/L)	7.62	7.94	7.97
Conductivity (µs/cm)	102.5	102.2	79.2
Chlorine	BDL	BDL	BDL
Turbidity (TU)	41	41	41
Arsenic	BDL	BDL	BDL
Water Temp (°C)	11	11.5	11.5

Photo 1: Water quality test at Dam site

Measured and Monitored by:

(Tandin Tshering)
Deputy Manager (Environment)
Druk Green Consultancy